DEPARTMENT OF THE INTERIOR
HUBERT WORK, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

BULLETIN 755

MINERAL RESOURCES OF ALASKA

REPORT ON PROGRESS OF INVESTIGATIONS IN

1922

BY

A. H. BROOKS AND OTHERS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1924

DEPARTMENT OF THE INTERIOR
HUBERT WORK, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Bulletin 755

MINERAL RESOURCES OF ALASKA

REPORT ON PROGRESS OF INVESTIGATIONS IN 1922

BY

A. H. BROOKS AND OTHERS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1924

CONTENTS.

	Page.
Preface, by A. H. Brooks	1
The Alaskan mining industry in 1922, by A. H. Brooks and S. R. Capps	3
Administrative report, by A. H. Brooks and G. C. Martin	51
The metalliferous deposits of Chitina Valley, by F. H. Moffit	57
Geology and mineral resources of the region traversed by the Alaska Railroad, by S. R. Capps	73
The Cold Bay-Chignik district, by W. R. Smith and A. A. Baker	151
Index	219
Recent Survey publications on Alaska	I

ILLUSTRATIONS.

	Page.
PLATE I. Geology and mineral deposits of the region tributary to the Alaska Railroad	88
II. Geologic sketch map of the western Talkeetna Mountains	120
III. Sketch map showing location of mines and prospects in the Willow Creek district	120
IV. Geologic sketch map of the Yentna district	128
V. Geologic sketch map of the upper Chulitna region	132
VI. Geologic sketch map of the Kantishna district	142
VII. Map showing position of lode mines and prospects and placer gravels in the Fairbanks district	144
VIII. Geologic reconnaissance map of the Cold Bay-Chignik district, Alaska Peninsula	154
IX. Geologic sketch map of Kejulik Valley	180
X. Geologic sketch map of vicinity of Pearl Creek dome and Mount Peulik	180
XI. Geologic sketch map of Wide Bay and vicinity	190
XII. Geologic sketch map showing Elephant Mountain anticline and vicinity	190
FIGURE 1. Index map showing location of the region traversed by the Alaska Railroad	73
2. Structure section from Mount Peulik to Portage Bay	202

MINERAL RESOURCES OF ALASKA, 1922.

By Alfred H. Brooks and others.

PREFACE.

By Alfred H. Brooks.

This volume is the nineteenth of a series of annual bulletins[1] summarizing the results achieved during the year in the investigation of the mineral resources of Alaska and treating of the mining industry of the Territory, especially of the statistics of mineral production, with the collection of which the Geological Survey is charged by law.

The reports included in this volume are primarily intended to give prompt publication of the more important economic results of the work of the year. The time available for their preparation does not permit full office study of the field notes and specimens, and some of the statements made here may require modification when the study has been completed. Those who are interested in any particular district should therefore procure a copy of the complete report on that district as soon as it is available.

Again, as for many years in the past, the Geological Survey is under great obligation to residents of the Territory for valuable data. Those who have thus aided include the many mine operators who have made reports on production as well as developments. There are still some Alaskan mineral producers, though a constantly decreasing number, who fail to respond to the request for information. Therefore it is still necessary to supplement the figures obtained from mine operators by estimates from other reliable sources. In this work the writer has received invaluable aid from many prospectors and miners, Federal and Territorial officials, engineers, and officers of banks and transportation and commercial companies.

It is impracticable to mention by name all who have aided in this work, but it should be stated that without the assistance of these public-spirited citizens the preparation of this report would have been

[1] The preceding volumes in this series are U. S. Geol. Survey Bulls. 259, 284, 314, 345, 379, 442, 480, 520, 542, 592, 622, 642, 662, 692, 712, 714, 722, and 739.

impracticable. Special mention should be made to B. D. Stewart, resident engineer of the Bureau of Mines; George Parks, of the General Land Office; the Director and other officers of the Bureau of the Mint; the Director and other officers of the Bureau of Mines; the officers of the Alaskan Engineering Commission; the American Railway Express Co.; Volney Richmond, of the Northern Commercial Co.; John C. McBride, H. T. Tripp, G. Jensen, Alaska-Juneau Gold Mining Co., and Jean Vanophem, of Juneau; Thomas Vogel, of Porcupine; John J. Kaznakoff, of Sitka; B. H. White and Thos. G. White, of Katalla; W. H. Dickey, of Rua Cove; G. Howard Birch, of Dan Creek; Kennecott Copper Corporation, of Kennicott; J. M. Elmer, of Dempsey; Thomas Larsen, of Kotsina; C. P. Tolson and W. G. Fenton, of Chickaloon; N. W. Sinclair, of Eska; H. W. Nagley and Edw. McConnell, of Talkeetna; T. S. Wolcott, of Colorado; Felix Brown and Alex Liska, of Anchorage; Fred Phillips, of Iliamna; D. E. Stubbs and Louis Huber, of Aniak; John Haroldson and A. Stecker, of Kwinak; W. F. Green and Peter McMullen, of McGrath; A. V. Thorns, of Tacotna; the First National Bank, George Hutchinson, J. E. Jennings, and T. H. Deal, of Fairbanks; Fred Schaupp, of Chatanika; Charles Zielke, Val Diebold, and John J. Murphy, of Nenana; Judson McLellan, Thos. McKinnon, and A. M. Bainbridge, of Tolovana; Alex. Mitchell, of Kantishna; George W. Ledger, of Rampart; C. E. Jones, of Ruby; B. B. Smith, Frank Speljack, and Edward Schneirla, of Ophir; H. S. Wanamaker, of Nolan; W. D. English, of Wiseman; George M. Pilcher, of Fortuna Ledge; James Funchion, A. W. Amero, and Fred J. Smith, of Caro; William Yanert, of Purgatory; Alfred Johnson, of Deadwood; J. J. Hillard and E. A. Robertson, of Eagle; J. H. Elden, of Steel Creek; Charles E. M. Cole, of Jack Wade; D. P. Thornton and Edward Briggen, of Chisana; A. J. Griffin, of Richardson; the Miners and Merchants Bank, Jack Gale, A. W. Kah, Anna Dukes, and R. W. J. Reed, of Nome; N. L. Wimmler, of the Bureau of Mines; S. M. Gaylord, of Solomon; the late W. N. Marx, of Teller; A. S. Tucker, of Bluff; Louis Lloyd, Michael Tuohy, and James C. Cross, of Shungnak; and George L. Stanley, of Kiana.

THE ALASKAN MINING INDUSTRY IN 1922.

By Alfred H. Brooks and S. R. Capps.

GENERAL SITUATION.

The value of the total annual mineral production of Alaska increased from $17,004,124 in 1921 to $19,506,365 in 1922.[1] Though this increase was due almost entirely to the larger copper output from a few mines, the prosperity of the mining industry as a whole was very evident.

The rather widespread pessimism in regard to the present and future prosperity of the Alaska mining industry is not hard to understand. Dazzled by the quick fortunes made during the prosperous days of bonanza placer mining, the public has failed to mark the steady advance of other and more permanent phases of mining that not only continued during the war but has been greatly accelerated in the last two years. The great publicity given to the failure of some of the large auriferous quartz mines near Juneau, for reasons later to be discussed, has entirely obscured the slow but steady development of other Alaska lode properties. The marked decline in the annual copper output since 1917, the result of low prices for the metal, has been erroneously interpreted as marking the decline of the Alaska copper-mining industry. The public, misled by widely circulated and grossly exaggerated statements of the value of Alaska coal lands, is puzzled by the apparent lack of progress in their exploitation. Thus far, indeed, discouraging results have met the rather meager underground exploration of the best Alaska coal. On the other hand, the furnishing of local coal to the region tributary to the Alaska Railroad is a very important advance, even though a reserve of export coal has not yet been developed. In like manner many who have long heard of the promising occurrences of petroleum in Alaska have wondered at the delay in its development. The explanation lies in the fact that oil drilling was prohibited from 1910 until 1920, when a leasing law was enacted. Since 1920 surface exploration of the oil fields has been very active, but it takes considerable time to start actual drilling in these distant fields. At the end of 1922 preparations for drilling in the Cold Bay district were well under way, and since then drilling has been started.

[1] The statistics in this report have been compiled by T. R. Burch.

Even Alaskans, many of whom are survivors of the days of bonanza mining, are by no means hopeful of the future. Those who have seen miners without capital grow suddenly wealthy from placer gold dug out with their own hands and who have beheld prosperous communities spring up almost over night are often impatient with mining projects that can succeed only by large investments and after years of preparation.

Some erroneously assume that the revival of mining in Alaska can be assured only by the discovery of a great mineral deposit, such as a large oil pool or a rich placer field, and no doubt only such a discovery could revive quickly the former prosperity of the Territory. Alaska mines have produced nearly half a billion dollars' worth of minerals, and 98 per cent of this amount has come from her deposits of gold, silver, and copper. The estimated known reserves of these metals alone, without regard to future discoveries or other minerals, such as oil and coal, are sufficient to assure a prosperous future for the mining industry.

Many appear to believe that the building of the Alaska Railroad should have immediately produced a marked boom. Now that a year has passed since the railroad began to furnish transportation and cheaper fuel and there has been no immediate increase of mineral output, they are loud in condemning the entire project. The Government railroad, as well as the greater activity in the building of wagon roads, has already stimulated mining, but it will be some time before the results of this work can be expressed in a notable increase in mineral production.

In spite of all despair or doubt the Alaskan mining industry is advancing, not retrograding. In fact, though the value of its present product is small compared with that of the past, the industry is now on a more substantial basis than ever before. In 1922 preparations for drilling were sufficiently advanced to assure the beginning of underground testing in 1923 of at least one of the Alaska petroleum fields; the installation of large placer-mining plants continued, and the work on some was so well advanced as to assure their operation in 1923; the activity in gold-lode development already noted for 1921 was continued; the copper production was about 43 per cent larger than in 1921, and there was a revival in the prospecting of copper deposits. Alaska's mining industry needs capital for its further development, and during the year there were many encouraging signs that large mining companies were turning their attention to Alaska as a prospective field for investment.

Estimates of number of men employed at productive mines of Alaska, 1911–1922.

Year.	Placer mines.		Lode mines and reduction plants.	All other mining and quarrying.	Total, not including winter placer mines.
	Summer.	Winter (omitted from total).			
1911	4,900	670	2,360	150	7,410
1912	4,500	900	2,500	150	7,210
1913	4,500	800	3,450	140	8,090
1914	4,400	800	3,500	140	8,040
1915	4,400	700	3,850	160	8,410
1916	4,050	880	4,570	340	8,960
1917	3,550	950	3,220	270	7,040
1918	3,000	610	2,000	400	5,400
1919	2,180	320	1,900	310	4,390
1920	1,990	340	1,880	360	4,230
1921	2,150	460	1,450	400	4,000
1922	2,198	402	1,200	410	3,808

In considering the above table it should be remembered that the summer placer mines are operated for an average period of less than 100 days in a year. A comparison of the first two columns shows that only a small percentage of the men engaged in summer placer mining can find similar employment in the winter. As the winter placer mining is all done through shafts and drifts it is closely related to lode mining. Some of the deep placer mines are operated for nearly the entire year and hence are included in the total summer mines also. The lode mines include copper and gold and a few other metal mines, and the figures for these include only the average number employed during the year. The fourth column shows the number of men engaged in all other forms of mining and quarrying, including the exploitation of coal, petroleum, marble, tin, gypsum, and other products.

Mineral output of Alaska, 1921 and 1922.

	1921		1922		Decrease or increase in 1922.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Gold........fine ounces..	390,558	$8,073,540	359,057	$7,422,367	−31,501	−$651,173
Copper.........pounds..	57,011,597	7,354,496	77,967,819	10,525,655	+20,956,222	+3,171,159
Silver.......fine ounces..	761,085	761,085	729,945	729,945	−31,140	−31,140
Coal.........short tons..	76,817	496,394	79,275	430,639	+2,458	−65,755
Tin, metallic......do....	4	2,400	1.40	912	−2.6	−1,488
Lead..............do....	759	68,279	377	41,477	−382	−26,802
Platinum metals, fine ounces..........	40	2,670	28.30	2,830	−11.70	+160
Miscellaneous nonmetallic products, including petroleum, marble, and gypsum..........	....	245,260	....	352,540	....	+107,280
Total............	....	17,004,124	....	19,506,365	....	+2,502,241

Value of total mineral production of Alaska, 1880–1922.

By years.				By substances.	
1880–1890	$4,686,714	1908	$20,145,632	Gold	$335,526,460
1891	916,920	1909	21,146,953	Copper	145,478,823
1892	1,098,400	1910	16,887,244	Silver	8,833,922
1893	1,051,610	1911	20,691,241	Coal	2,723,161
1894	1,312,567	1912	22,536,849	Tin	937,576
1895	2,388,042	1913	19,476,356	Lead	772,014
1896	2,981,877	1914	19,065,666	Antimony	237,500
1897	2,540,401	1915	32,854,229	Marble, gypsum, petroleum, platinum, etc	3,475,822
1898	2,587,815	1916	48,632,212		497,985,278
1899	5,706,226	1917	40,710,205		
1900	8,241,734	1918	28,253,961		
1901	7,010,838	1919	19,620,913		
1902	8,403,153	1920	23,303,757		
1903	8,944,134	1921	17,004,124		
1904	9,569,715	1922	19,506,365		
1905	16,480,762				
1906	23,378,428		497,985,278		
1907	20,850,235				

GOLD AND SILVER.

TOTAL PRODUCTION.

In 1850 and 1851 a Russian mining engineer, P. P. Doroshin, with a large force of men, did some placer mining in the Kenai River Basin, about 140 miles west of the present location of Seward. This project was soon abandoned and, except for the exploitation of some lignitic coal near Port Graham, was the only mining attempted by the Russians in their American colony during the 80 years of its occupation.

In 1861 some gold was found in the bars of Stikine River, but by subsequent surveys this locality proved to be on the Canadian side of the boundary. No important mining was done here, but the discovery resulted in the first gold stampede to Alaska. The Stikine Valley was soon abandoned by the prospectors, however, and did not again attract attention until it was much used as a highway into the Cassiar gold district, discovered in 1871. Wrangell, in southeastern Alaska, then became the coastal port for the new placer camps, and prospectors began to turn their attention to the adjacent region. It is reported that about this time many thousand dollars' worth of gold was mined on Shuck River, emptying into Windham Bay, about 70 miles south of the present site of Juneau. This report is unverified and probably has little foundation; in fact, some of the Wrangell prospectors extended their search for gold to Sitka and in 1872 found auriferous quartz in that region. The first mining was done by Michael Haley, who had come north as a soldier but was an experienced miner. In 1879 George F. Pilz, a German mining engineer, opened up the Stewart mine, near Sitka. Pilz was the first educated mining engineer, opened the first quartz mine, and built the first mill in Alaska. In 1880 Richard T. Harris and Joseph Juneau found auriferous quartz and placer gold near the present site of Juneau. The great Alaskan mining industry, the total product of

which is valued at nearly half a billion dollars, began with gold-placer mining at Juneau 42 years ago.

Gold and silver produced in Alaska, 1880–1922.

Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Commercial value.
1880	967	$20,000		
1881	1,935	40,000		
1882	7,256	150,000		
1883	14,561	301,000		
1884	9,724	201,000	10,320	$11,146
1885	14,512	300,000		
1886	21,575	446,000		
1887	32,653	675,000		
1888	41,119	850,000	2,320	2,181
1889	43,538	900,000	8,000	7,490
1890	36,862	762,000	7,500	6,071
1891	43,538	900,000	8,000	7,920
1892	52,245	1,080,000	8,000	7,000
1893	50,213	1,038,000	8,400	6,570
1894	62,017	1,282,000	22,261	14,257
1895	112,642	2,328,500	67,200	44,222
1896	138,401	2,861,000	145,300	99,087
1897	118,011	2,439,500	116,400	70,741
1898	121,760	2,517,000	92,400	54,575
1899	270,997	5,602,000	140,100	84,276
1900	395,030	8,166,000	73,300	45,494
1901	335,369	6,932,700	47,900	28,598
1902	400,709	8,283,400	92,000	48,590
1903	420,069	8,683,600	143,600	77,843
1904	443,115	9,160,000	198,700	114,934
1905	756,101	15,630,000	132,174	80,165
1906	1,066,030	22,036,794	203,500	136,345
1907	936,043	19,349,743	149,784	98,857
1908	933,290	19,292,818	135,672	71,906
1909	987,417	20,411,716	147,950	76,934
1910	780,131	16,126,749	157,850	85,239
1911	815,276	16,853,256	460,231	243,923
1912	829,436	17,145,951	515,186	316,839
1913	755,947	15,626,813	362,563	218,988
1914	762,596	15,764,259	394,805	218,327
1915	807,966	16,702,144	1,071,782	543,393
1916	834,068	17,241,713	1,379,171	907,495
1917	709,049	14,657,353	1,239,150	1,021,060
1918	458,641	9,480,952	847,789	847,789
1919	455,984	9,426,032	629,708	705,273
1920	404,683	8,365,560	953,546	1,039,364
1921	390,558	8,073,540	761,085	761,085
1922	359,057	7,422,367	729,945	729,945
	16,231,091	335,526,460	11,463,592	8,833,922

Gold and silver produced in Alaska, 1922, by sources.

	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.
Siliceous ores (2,513,455 short tons)	145,883	$3,015,669	71,886	$71,886
Copper ores (581,384 short tons)	561	11,596	622,978	622,978
Lead ores (79 short tons)	5	102	8,712	8,712
Placers (5,225,274 cubic yards of gravel)	212,608	4,395,000	26,369	26,369
	359,057	7,422,367	729,945	729,945

Gold and silver produced in Alaska from different sources, 1880–1922.

	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.
Siliceous ores [a]	4,993,626	$103,227,434	1,948,761	$1,595,477
Copper ores	86,689	1,792,034	7,666,126	6,125,041
Placers	11,150,776	230,506,992	1,848,705	1,113,404
	16,231,091	335,526,460	11,463,592	8,833,922

[a] Including small amounts of galena ore.

GOLD LODES.

For many years the Alaskan gold-lode mining industry was almost entirely based on the Treadwell property, in the Juneau district. The profitable exploitation of this enormous ore body, containing not more than $2.50 worth of gold to the ton, long ago brought proof that the cost of mining in tidewater Alaska was not necessarily excessive. This very profitable venture led to the development of two other large ore bodies in the same district, the Alaska-Juneau and Perseverance. The metallic content of these ores is much lower than that of the Treadwell ore, but it was believed that this handicap could be offset by the use of cheaper mining and milling methods. The Perseverance (Alaska Gastineau) plant was completed in 1916 and the Alaska-Juneau in 1917, and therefore at the very outset these plants met the adverse industrial conditions imposed by the World War. In addition, other difficulties arose relating to irregularity in the distribution of gold as well as to mining and milling. As a consequence, the Perseverance mine finally closed in 1921; the Alaska-Juneau, however, by improving its practice, increased its output in 1922 over that of 1921.

In 1917 came the Treadwell disaster—the caving and flooding of two of the three large mines. As a result of the abandonment of three of the five large mines of the Juneau district the value of the annual gold output decreased from $4,570,000 in 1916 to $1,573,000 in 1922. The most encouraging fact about the Alaskan lode-mining industry is that the loss of output from these large gold mines has already in part been made up by the output of the smaller mines of other districts. The total gold-lode output of Alaska in 1916 had a value of $5,900,000 and in 1922 about $3,015,771. The reduction is therefore only 47 per cent for all Alaska, while that of the Juneau district has been 65 per cent.

The facts above set forth are cited because many believe that the closing of some of the Juneau mines means the end of any considerable quartz mining in Alaska. This is not true even at Juneau, and in all

other Alaska lode districts that are accessible by railroad or tidewater the development and prospecting of hard-rock gold deposits are actively going on.

Though the gold-silver deposits of the Salmon River district are not yet productive, the outlook for profitable mining is good. The development of mines in the Juneau district is more active than for several years. On Chichagof Island, in the Sitka district, one additional mine, the Hirst-Chichagof, began producing in 1922, and several other properties are being developed. The small gold mines on Prince William Sound will probably soon react to the cheapening of fuel by coal furnished from the Matanuska field. The Willow Creek district, now accessible by railroad and good roads, is making excellent progress in lode mining. In 1922 the value of the output from the seven small mines of the district was $238,000, as against $118,000 in 1921; but more important than this gain of more than 100 per cent is the fact that at last systematic underground exploration has begun. In the Fairbanks district the completion of the Alaska Railroad and the assurance of comparatively cheap fuel from the Nenana coal field have stimulated lode development. Five mines and prospects produced gold to the value of $54,000 in 1922, as compared with $38,000 in 1921. There are in the Fairbanks district at least a score of lode properties which under present conditions are worthy of further exploration. In addition to the productive districts, there are many other regions in Alaska where auriferous lodes have been found.

Twenty-five gold and silver lode mines and six prospects [2] were operated in 1922 and produced gold, silver, and some lead and copper to a total value of $3,138,585; in 1921 19 gold and silver lode mines and 13 prospects were operated and produced metals to a total value of $4,082,741. These values do not include the gold and silver recovered from the copper lode mines. In general, the lode-mining industry in 1922 showed progress during the year, but developments of ore bodies are not yet sufficient to give any assurance that the output of gold from this source will increase in the immediate future. At the same time the outlook for an early increase in lode-gold production from the Sitka, Willow Creek, and Fairbanks districts is exceedingly good.

[2] Lode properties the value of whose total metallic output is less than $1,000 are here classed as prospects. These include some mines on which considerable development work has been done but which have not yet been put on a regular productive basis.

Gold and silver produced from gold-lode mines in Alaska in 1922, by districts.

District.	Ore mined (short tons).	Gold.		Silver.		Average value per ton of ore in gold and silver.
		Fine ounces.	Value.	Fine ounces.	Value.	
Southeastern Alaska	[a] 2,501,542	124,796.11	$2,579,764	67,590	$67,590	$1.06
Willow Creek	7,242	11,513.25	238,000	1,500	1,500	33.07
Fairbanks district	1,724	2,612.25	54,000	490	490	31.60
Other districts	3,026	6,965.82	144,007	11,018	11,018	51.23
	2,513,534	145,887.43	3,015,771	80,598	80,598	1.23

[a] Including small amounts of galena ore.

In the above table are included silver-lead ores as well as auriferous quartz. The ore hoisted from auriferous quartz mines yielded an average of $1.23 worth of gold and silver to the ton. In 1921 the average recovery was $1.39. The low recovery in 1922 was caused by the large percentage of the total tonnage furnished by the Juneau mines. If these mines, which handle ore of very low grade, are eliminated, the average recovery from the other mines included in the table is $29.27 to the ton.

GOLD PLACERS.

Placer mining has been done in Alaska since 1880 and has yielded gold having a total value of $230,000,000. Of this total more than $200,000,000 has been mined since 1900, when the industry received its first great stimulus by the gold output of the Nome district. Other bonanza deposits were soon discovered, and by 1906 the value of the annual output of placer gold had reached $18,600,000 and the industry employed about 8,000 men. From 1906 the annual output declined, and by 1913 its value was reduced to $10,680,000 and the number of miners to 4,700. It should be noted that this reduction (45 per cent) in the value of the placer output took place before the war and that it indicated the rapid exhaustion of the bonanza deposits. From 1914 to 1917 the average value of annual output of placer gold was about $10,000,000, and if the general industrial conditions had remained the same and railroad and road building and the development of coal and petroleum had been accelerated, the annual placer output would probably not have declined below this amount. But after 1917 the war began to affect Alaska industries seriously, and placer mining rapidly declined, reaching its minimum in 1920, when the value of the output was only $3,873,000. Since then, however, it has somewhat increased.

During the period of bonanza placer mining the cost of operation was gradually but constantly lowered by improved methods of mining, especially in gold dredging, the output of which increased in value from $20,000 in 1903 to $2,200,000 in 1913. Dredges had been built so actively before the war that, in spite of adverse conditions,

they continued to increase their output, which did not reach its maximum until 1916, when its value was $2,679,000. The hard times that followed led not only to the shutting down of dredges already built but to the abandonment of some new projects. The dredges reached their minimum output of gold in 1920, when its value was $1,130,000. This rise and decline of gold dredging before 1920 was paralleled by a similar though smaller fluctuation in hydraulic and other mechanical mining.

The passage from almost strictly manual to mechanical methods of placer mining was well under way when it was checked by the war. Had it not been thus interrupted the transition would have been more gradual, and it would not have dealt so severe a blow to the communities supported by the returns from placer mining.

Everyone who is interested in the prosperity of Alaska, which in the past has been so largely built upon the returns from placer mining, will naturally ask the question whether the gold placer reserves are sufficient to support again a large industry. In 1919 [3] an attempt was made to estimate the value of the placer gold still unmined. Such an estimate could not of course take account of possible new discoveries; it must include only those areas of auriferous gravel that have been more or less prospected. Fine colors of gold are likely to be found in most Alaska streams, but only a few of these streams contain workable placers. A rough estimate, which includes only the auriferous gravel whose gold content is large enough to be profitably exploited by methods now used, shows that there is still about $350,000,000 worth of placer gold in the ground in Alaska. This estimate is based on very incomplete data, and its value should therefore not be overrated, but it at least indicates the magnitude of the true figures, and it certainly shows that the Alaska placers are by no means approaching exhaustion.

In this connection an instructive comparison may be made between the placer mining in Alaska and that in the Klondike district, in the Canadian Yukon. During the eight years of bonanza placer mining ending about 1905 this district produced $107,000,000 in gold. It was then generally believed that the days of placer mining there were about over, but by use of hydraulic and dredging plants the district has since produced gold worth more than $70,000,000. Yet compared with placer mining in the Klondike, placer mining in Alaska is but in its infancy.

Though the outlook for large-scale placer mining in Alaska is very encouraging, yet it can not be denied that in many districts the day of profitable small operations is rapidly passing.[4] Where the rich placers have been mined out, as they have been in many camps, the individual operator who has little or no capital can not

---

[3] Brooks, A. H., The future of Alaska mining: U. S. Geol. Survey Bull. 714, pp. 7–11, 1921.

[4] Brooks, A. H., The Alaskan mining industry in 1920: U. S. Geol. Survey Bull. 722, pp. 14–17, 1922.

profitably exploit the deposits of lower grade. If such deposits are large enough they will be worked by more economical methods, but if not the work on them must be abandoned. It is also clear that the operations of large companies will not support settlements that have been built up on the returns from bonanza mining. A dredge employing say 15 men may do the work of several hundred with consequent loss to the local community. In many districts this loss will be more than offset by the business developed through lode mining or other new industries. Some settlements, however, are bound to decline, and some will be entirely abandoned.

The interests of placer mining can be best served by affording cheaper transportation and fuel, a fact shown by the stimulating effect on placer mining of only one year's operation of the Alaska Railroad. The life of many of the districts in which the operations are small can be much prolonged by the building of wagon roads, which at the same time attract enterprises requiring large capital.

About 507 Alaska placer mines, employing 2,198 men, were operated during the summer of 1922, and 120, employing 402 men, during the preceding winter. These mines produced gold to the value of $4,395,000. In 1922 many more men than for several years in the past were employed in installing large mining plants that are as yet unproductive. It is certain that when the plants now being installed are operated the output of placer gold will be increased; it will be larger in 1923 than it was in 1922.

Statistics of placer mining in Alaska in 1921 and 1922.

Region.	Number of mines.				Number of miners.				Value of gold produced.		
	Summer.		Winter.		Summer.		Winter.		1921	1922	Decrease or increase, 1922.
	1921	1922	1921	1922	1921	1922	1921	1922			
Southeastern and southwestern Alaska	7	2	3	1	11	3	3	2	$4,000	$3,000	−$1,000
Copper River region	7	8	2	5	130	91	14	18	220,000	165,000	−55,000
Cook Inlet and Susitna region	34	36	2	1	144	174	29	2	165,000	293,000	+128,000
Yukon basin	334	321	79	99	1,131	1,254	335	321	1,860,000	2,119,000	+259,000
Kuskokwim region	28	30	3	......	98	137	8	......	520,000	542,000	+22,000
Seward Peninsula	126	104	13	11	622	528	61	51	1,450,000	1,265,000	−185,000
Kobuk region	9	6	4	3	15	11	10	8	7,000	8,000	+1,000
	545	507	106	120	2,151	2,198	460	402	4,226,000	4,395,000	+169,000

Gold and silver produced from placer mines in Alaska in 1922, by regions.

Region.	Gold.		Silver.		Gravel mined.	
	Fine ounces.	Value.	Fine ounces.	Value.	Cubic yards.	Recovery per cubic yard.
Southeastern Alaska	145.13	$3,000	23	$23	1,800	$1.67
Copper River region	7,981.88	165,000	851	851	305,747	.54
Cook Inlet and Susitna region	14,173.88	293,000	2,095	2,095	593,788	.49
Yukon basin	102,506.61	2,119,000	13,751	13,751	1,999,167	1.01
Kuskokwim region	26,219.25	542,000	2,815	2,815	215,950	2.50
Seward Peninsula	61,194.37	1,265,000	6,790	6,790	2,103,691	.60
Kobuk region	387.00	8,000	44	44	5,857	1.37
	212,608.12	4,395,000	26,369	26,369	5,226,000	.84

In the early days of mining on the Yukon it was generally considered that a placer miner must recover at least $20 a day during the short working season if he was to be profitably employed. Indeed, fortunes were believed to come only to those who were gaining each day a still larger quantity of gold from the gravels. Experience has shown that in most Alaska districts a wage of $10 a day from a mine operated only by manual methods is considered to be a good venture. These figures expressed in value per cubic yard of gravel sluiced would be about $4 for the old days and $2 for the present. In the first two years of mining on Seward Peninsula the minimum profitable return was about $5 to the cubic yard; now, with the large use of dredges, it averages less than 70 cents. In spite of the fact that much the larger part of the present-day placer mining in Alaska is done on gravel carrying a lower percentage of gold than that of the gravel that has already been mined, the average profit is much larger. This gain is of course due to the decreased cost of mining, which has resulted both from improvements in the methods employed and from the lowering of cost of transportation. This gradual lowering of cost is demonstrated by the following tables, which are based in part on returns made by operators of placer mines and in part on known facts or assumptions concerning the richness of the gravel in the several districts. Although the tables are thus in part estimates, they are probably nearly correct. The decline in the average gold content of the gravel mined from 1908 to 1914 reflects the gradual exhaustion of bonanza placers, the improvement in methods of placer mining, and especially the increased use of dredges.

Gravel sluiced in Alaskan placer mines and value of gold recovered, 1908–1922.

Year.	Total quantity of gravel (cubic yards).	Value of gold recovered per cubic yard.	Year.	Total quantity of gravel (cubic yards).	Value of gold recovered per cubic yard.
1908	4,275,000	$3.74	1916	7,100,000	$1.57
1909	4,418,000	3.66	1917	7,000,000	1.40
1910	4,036,000	2.97	1918	4,931,000	1.20
1911	5,790,000	2.17	1919	4,548,000	1.10
1912	7,050,000	1.70	1920	3,439,900	1.13
1913	6,800,000	1.57	1921	4,812,700	.88
1914	8,500,000	1.26	1922	5,226,000	.84
1915	8,100,000	1.29			

Relation of recovery of placer gold per cubic yard to proportion produced by dredges.

Year	Percentage of placer gold produced by dredges.	Recovery per cubic yard.			Year.	Percentage of placer gold produced by dredges.	Recovery per cubic yard.		
		Dredges.	Mines.	All placers.			Dredges.	Mines.	All placers.
1911	12	$0.60	$3.36	$2.17	1917	26	$0.68	$2.21	$1.40
1912	18	.65	2.68	1.70	1918	24	.57	1.84	1.20
1913	21	.54	3.11	1.57	1919	27	.77	1.31	1.10
1914	22	.53	2.07	1.26	1920	29	.69	1.53	1.13
1915	22	.51	2.33	1.29	1921	37	.57	1.31	.88
1916	24	.69	2.64	1.57	1922	40	.55	1.29	.84

Now that the means of transportation are improving and it is becoming recognized that there are large areas of dredging ground in Alaska, this form of mining is being more widely extended. In the summer of 1922, after two years of systematic prospecting, two dredges, the largest in Alaska, were built at Nome, with buckets holding 9 cubic feet and 40 and 60 foot ladders. A strong company was also engaged in extensive prospecting of dredging ground in the Fairbanks district. During the summer a dredge was being taken to Gaines Creek, in the Innoko district, and another to Minook Creek, in the Rampart district, so that four new gold dredges will be installed in Alaska in 1923. In 1922, 23 dredges produced gold worth $1,767,753; in 1921, 24 dredges produced gold worth $1,582,520. Of the 23 dredges operated in 1922, 15 were in Seward Peninsula, 2 each in the Iditarod and Fairbanks districts, and 1 each in the Innoko, Mount McKinley (Upper Kuskokwim), Circle, and Yentna (Susitna) districts. The dredges in Seward Peninsula produced about $609,859 worth of gold in 1922.

Gold dredges operated in Alaska in 1922.

Seward Peninsula:
- Council district:
  - Crooked Creek Dredge Co., Crooked Creek.
  - Garrod & Overbaugh, Warm Creek.
  - Northern Light Mining Co., Ophir Creek.
  - Wild Goose Mining & Trading Co. (2 dredges), Ophir Creek.
- Kougarok district, Behring Dredging Corporation, Kougarok River.
- Nome district:
  - Ames & Guinan, Glacier Creek.
  - Bangor Dredging Co., Anvil Creek.
  - Center Creek Dredging Co., Snake River.
  - Dexter Creek Dredging Co., Dexter Creek.
  - Frank Hall, Arctic Creek.
  - Julien Dredging Co., Osborn Creek.
- Solomon district:
  - Eskimo Gold Dredging Co., Solomon River.
  - Iverson & Johnson, Big Hurrah Creek.
  - Shovel Creek Dredging Co. (Nylen, Hultberg, and others), Shovel Creek.

Yukon basin:
- Circle district, Berry Dredging Co., Mastodon Creek.
- Fairbanks district, Fairbanks Gold Dredging Co. (2 dredges), Fairbanks Creek.
- Iditarod district:
  - Beaton & Donnelly, Otter Creek.
  - J. E. Riley Investment Co., Otter Creek.
- Innoko district, Flume Dredge Co., Yankee Creek.

Kuskokwim region:
- Mount McKinley district, Kuskokwim Dredging Co., Candle Creek.

Cook Inlet and Susitna region:
- Yentna district, Cache Creek Dredging Co., Cache Creek.

Gold produced by dredge mining in Alaska, 1903–1922.

Year.	Number of dredges operated.	Value of gold output.	Gravel handled (cubic yards).	Value of gold recovered per cubic yard.
1903	2	$20,000	....	....
1904	3	25,000	....	....
1905	3	40,000	....	....
1906	3	120,000	....	....
1907	4	250,000	....	....
1908	4	171,000	....	....
1909	14	425,000	....	....
1910	18	800,000	....	....
1911	27	1,500,000	2,500,000	$0.60
1912	38	2,200,000	3,400,000	.65
1913	35	2,200,000	4,100,000	.54
1914	42	2,350,000	4,450,000	.53
1915	35	2,330,000	4,600,000	.51
1916	34	2,679,000	3,900,000	.69
1917	36	2,500,000	3,700,000	.68
1918	28	1,425,000	2,490,000	.57
1919	28	1,360,000	1,760,000	.77
1920	22	1,129,932	1,633,861	.69
1921	24	1,582,520	2,799,519	.57
1922	23	1,767,753	3,186,343	.55
	....	24,875,205	....	....

COPPER MINING.

A little copper mining was done at Kasaan Bay, in the Ketchikan district, as early as 1880, but this project was soon abandoned. About 1899 the copper deposits of Ketchikan and Prince William Sound began to receive attention, and in 1900 small shipments began.

The production of a large output of copper in Alaska began with the opening of the Kennecott mines after the completion of the Copper River & Northwestern Railway in 1911. In the next four years the annual output averaged 25,000,000 pounds. By 1916, under the stimulus of war prices, the output had been increased to 119,654,000 pounds. Since then, in consequence of the slump in the copper market, the annual output of the metal in Alaska has in general gradually decreased, reaching its lowest point in 1919, when it was 47,000,000 pounds. In spite of the continued low price of copper, the output in 1922 was 77,967,819 pounds. Alaska has now produced a total of 751,086,642 pounds of copper.

Most of the copper mined in 1922 was obtained from the three large mines of the Kennecott group in the Chitina Valley, and from the Beatson-Bonanza mine, on Prince William Sound. In 1922, as in many other years, copper was produced also at the Rush & Brown mine, in the Ketchikan district. A small output of copper was also made from mines in the upper Kuskokwim Valley and in some other districts. The low price of the metal has prevented the owners of many small mines from renewing operations, but there was some revival of interest in prospecting copper lodes in 1922, notably in the Chitina Valley. The advance in the price of copper will undoubtedly reanimate copper-mining activities in Alaska.

The average copper content of the ore mined in 1922 was 6.7 per cent. The ores yielded an average of $0.020 in gold and $1.07 in silver to the ton. The average yield in 1921 was 5.8 per cent of copper and $0.024 in gold and $1.14 in silver.

Of the total copper ore mined in Alaska in 1922, 94 per cent, or 544,212 tons, was concentrated and yielded 53,572 tons of concentrates, which averaged 45 per cent of copper. Most of the copper ore mined in 1922 was shipped to the Tacoma smelter, but a part of that mined in southeastern Alaska was treated elsewhere.

Copper produced in Alaska, 1880–1922.

Year.	Mines operated.	Ore mined (tons).	Copper produced.	
			Pounds.	Value.
1880	1	20	3,933	$826
1900	1	500	100,000	16,000
1901	2	1,350	270,000	44,000
1902	3	2,750	510,000	59,000
1903	4	9,000	1,730,000	224,510
1904	4	15,000	2,843,586	376,076
1905	8	52,199	3,481,771	542,155
1906	15	105,739	6,459,803	1,246,682
1907	13	98,927	6,308,786	1,261,757
1908	9	51,509	4,585,362	605,267
1909	7	34,669	4,124,705	536,211
1910	7	39,365	4,241,689	538,695
1911	8	68,975	27,267,878	3,408,485
1912	7	93,452	29,230,491	4,823,031
1913	6	135,756	21,659,958	3,357,293
1914	6	153,605	21,450,628	2,852,934
1915	14	369,600	86,509,312	15,139,129
1916	18	617,264	119,654,839	29,484,291
1917	17	659,957	88,793,400	24,240,598
1918	17	722,047	69,224,951	17,098,563
1919	8	492,644	47,220,771	8,783,063
1920	8	766,095	70,435,363	12,960,106
1921	6	477,121	57,011,597	7,354,496
1922	5	581,384	77,967,819	10,525,655
	....	5,548,928	751,086,642	145,478,823

SILVER-LEAD DEPOSITS.

No marked advances were made in 1922 in the development of deposits of galena. The Moonshine property, in the Ketchikan district, long idle, was reopened. Work was continued on the lodes of the Salmon River district (Portland Canal), which carry a high content of silver. In the Kantishna district the prospecting of galena ores continued with encouraging results, but systematic and large underground exploration must await the construction, already begun, of wagon roads to the Alaska Railroad. So far as now known, the Perseverance claim, in the Ruby district, and the Quigley mine, in the Kantishna district, were the only galena deposits mined in 1922. The output from these properties and the by-product from the Alaska-Juneau mine appear to have been the source of all the lead produced in Alaska in 1922. The Alaska lead output is as yet but small and in the past has fluctuated with the mining of gold and

copper. The silver produced in 1922, estimated at 729,945 ounces, was only in small part derived from these galena deposits, for most of it was a by-product of gold and copper mining.

Lead produced in Alaska, 1892–1922.

Year.	Tons.	Value.	Year.	Tons.	Value.
1892	30	$2,400	1908	40	$3,360
1893	40	3,040	1909	69	5,934
1894	35	2,310	1910	75	6,600
1895	20	1,320	1911	51	4,590
1896	30	1,800	1912	45	4,050
1897	30	2,160	1913	6	528
1898	30	2,240	1914	28	1,344
1899	35	3,150	1915	437	41,118
1900	40	3,440	1916	820	113,160
1901	40	3,440	1917	852	146,584
1902	30	2,460	1918	564	80,088
1903	30	2,520	1919	687	72,822
1904	30	2,580	1920	875	140,000
1905	30	2,620	1921	759	68,279
1906	30	3,420	1922	377	41,477
1907	30	3,180		6,195	772,014

TIN.

The price of tin has been too low to encourage the further operation of Alaska tin mines. In 1922 the only tin produced was that taken from the gold placer mines of the Hot Springs district. About 700 pounds of stream tin was shipped from Nome, however, but so far as known this was all mined before 1922 and has therefore been previously included in the statistics of Alaska tin production.

Tin produced in Alaska, 1902–1922.

Year.	Ore (tons).	Metal (tons).	Value.	Year.	Ore (tons).	Metal (tons).	Value.
1902	25	15	$8,000	1914	157.5	104	$66,560
1903	41	25	14,000	1915	167	102	78,846
1904	23	14	8,000	1916	232	139	121,000
1905	10	6	4,000	1917	171	100	123,300
1906	57	34	38,640	1918	104.5	68	118,000
1907	37.5	22	16,752	1919	86	56	73,400
1908	42.5	25	15,180	1920	26	16	16,112
1909	19	11	7,638	1921	7	4	2,400
1910	16.5	10	8,335	1922	2.3	1.4	912
1911	92.5	61	52,798				
1912	194	130	119,600		1,609.3	993.4	937,576
1913	98	50	44,103				

PLATINUM METALS.

There were no developments during 1922 in mining the platinum minerals in Alaska. The Salt Chuck copper-palladium mine, in the Ketchikan district, was closed throughout the year. The only platinum produced was that recovered incidentally to gold placer mining by about five operators, mostly in Seward Peninsula and the Chisana district.

Platinum metals produced in Alaska, 1916–1922.

Year.	Crude ounces.	Fine ounces.	Value.	Year.	Crude ounces.	Fine ounces.	Value.
1916	12.0	8.33	$700	1920	1,493.4	1,478.97	$160,117
1917	81.2	53.40	5,500	1921	57.0	40.00	2,670
1918	301.0	284.00	36,600	1922	39.0	28.30	2,830
1919	579.3	569.52	73,663		2,562.9	2,462.52	282,080

MISCELLANEOUS METALS.

Deposits of quicksilver, antimony, chromite, tungsten, and molybdenite occur in Alaska and have been mined in the past. In 1922 the output of these metals was confined to a small amount of scheelite (tungsten ore) recovered from gold placer mining near Nome. Some development work was continued on the nickel deposits of Chichagof Island and on the quicksilver-bearing lodes in the lower Kuskokwim River. Work was also done on a bismuth-bearing lode in the Bonnifield (Nenana) district of the Tanana Valley.

COAL.

In 1922 a total of 79,275 tons of coal was produced in Alaska, of which over 90 per cent was the output of private mines, and the rest came from the Government mines. In 1921 only 30 per cent of the coal output was produced from private mines. Evidently, therefore, the development of the mining of coal for local use is well under way. It is certain that Alaska's coal consumption will expand with the demands of mining and other industries, and much of this increased use will be met by the product of Alaskan mines. It is not likely that the subbituminous and lignitic coal now locally mined can compete with the imported fuel now used in southeastern Alaska. On the other hand, central Alaska, including the region along the Alaska Railroad, Kenai Peninsula, Prince William Sound, Alaska Peninsula, and probably the region along the Copper River & Northwestern Railway, form an industrial province which should draw its fuel from Alaskan sources. The industrial developments under way in this province should soon double the demand for coal, but even then the market will not exceed 200,000 tons. Interesting possibilities for the use of Matanuska coal for bunkering were opened in 1922 by the supplying of the U. S. collier *Jason* with 5,000 tons of coal from the Chickaloon mine. Fuel for Seward Peninsula is now all imported and is predominantly petroleum. Plans have been considered for utilizing the enormous deposits of coal near Cape Lisburne to supply the Bering Sea region. The Cape Lisburne region includes very high-grade bituminous coal as well as enormous bodies of subbituminous coal, and these form the largest coal reserve of northwestern Alaska and probably a larger reserve than any in northeastern Siberia. The shipping season from Cape Lisburne is only two months long, which

is a serious handicap to the project, but in spite of the difficulties in exploitation, these coals will in time be drawn upon to supply the country around Bering Sea.

The high-grade coals of the Bering River and Matanuska field are not yet sufficiently developed to give assurance that they can find a market in competition with fuels from other fields, which can be mined much more cheaply. As they are the best coals on the Pacific seaboard of North America, however, it is only a question of time when they must be utilized.

To summarize the Alaska coal situation: The mining of the lower-grade coals for local use will increase considerably, though no large market for these coals can be expected in the immediate future. Underground exploration of the higher-grade coals of Bering River and Matanuska will be continued. The mining of these coals will depend on the discovery of beds that will be cheaper to mine because they are less disturbed than those at present known, or on an increase in the demand for coal on the Pacific, which would force the mining of expensive fuels. Evidently such an increase in demand is involved with the future of petroleum production. If petroleum can not be drawn upon to supply the constantly increasing demand for fuel, the Alaska coal will have to be utilized. In this connection the possibility that Alaska may furnish a large petroleum supply should be considered.

Coal produced and consumed in Alaska, 1888–1922, in short tons.

Year.	Produced in Alaska, chiefly subbituminous and lignite.		Imported from States, chiefly bituminous from Washington.[a]	Total foreign coal, chiefly bituminous from British Columbia.[a]	Total coal consumed.
	Short tons.	Value.			
1888–1896	6,000	$84,000	....	....	....
1897	2,000	28,000	....	....	....
1898	1,000	14,000	....	....	....
1899	1,200	16,800	10,000	[b] 50,120	61,320
1900	1,200	16,800	15,048	[b] 56,623	72,871
1901	1,300	15,600	24,000	[b] 77,674	102,974
1902	2,212	19,048	40,000	[b] 68,363	110,575
1903	1,447	9,782	64,626	[b] 60,605	126,678
1904	1,694	7,225	36,689	[b] 76,815	115,198
1905	3,774	13,250	67,713	[b] 72,612	144,099
1906	5,541	17,974	69,493	[b] 47,590	122,624
1907	10,139	53,600	46,246	[b] 93,262	149,647
1908	3,107	14,810	23,893	[b] 86,404	113,404
1909	2,800	12,300	33,112	69,046	104,958
1910	1,000	15,000	32,098	58,420	91,518
1911	900	9,300	32,255	61,845	95,000
1912	355	2,840	27,767	68,316	96,438
1913	2,300	13,800	69,066	56,430	127,796
1914	....	....	41,509	46,153	87,662
1915	1,400	3,300	46,329	29,457	77,186
1916	13,073	52,317	44,934	53,672	111,679
1917	53,955	265,317	58,116	56,589	168,660
1918	75,606	411,850	51,520	37,986	165,112
1919	60,674	343,547	57,166	48,708	166,548
1920	61,111	355,668	38,128	45,264	144,503
1921	76,817	496,394	24,278	33,776	134,871
1922	79,275	430,639	28,457	27,021	134,753
Total	469,880	2,723,161	982,443	1,382,751	2,826,074

[a] No figures on imports before 1899 are available. [b] By fiscal year ending June 30.

In 1922 coal was mined at about 12 localities. Some of the operations were small, there being only 7 that produced more than 1,000 tons each. Coal-land exploration was continued in the Matanuska field throughout most of the year by either the Alaska Naval Coal Commission or the Alaskan Engineering Commission. Incidentally to this work 5,297 tons of coal was produced. The Jones mine was worked until the later part of November, when operation was temporarily suspended on account of a fire. Because of this suspension, the Eska mine of the Alaskan Engineering Commission was reopened and produced 2,611 tons of coal before the end of the year. Some coal was also produced at the Baxter mine, and there were small operations at other localities in the field. A large sample of Government coal from the Matanuska field was washed and shipped out for a naval test in 1922.

The only coal mined during the year in the Bering River field was a sample sent out from the Carbon Creek mine for naval tests and some mined on the Alaska Petroleum Co.'s property incidentally to development work. Some progress was made on the project for a railroad from Katalla to the heart of the field.

Of the coal mined during 1922, 23,636 tons was lignite, most of which came from the Nenana field, where two mines were operated. The Broad Pass Coal & Development Co. worked a mine from July to December. The Healy River Corporation continued operating its mine on the west bank of Nenana River until July. It then turned its main efforts to another property on the east side of the Nenana, to which a spur from the railroad was completed in October, when coal production began.

A few coal banks were worked for local use in the Broad Pass region. As in the past, the Bluff mine, on Cook Inlet, was operated. In northern Alaska lignitic coal was mined at three localities—at the Kugruk mine, on Seward Peninsula; on Kobuk River; and at Wainwright Inlet for use of natives. The total output from these operations was about 500 tons.

PETROLEUM.

Plans are under way for testing by drilling in nearly all the Alaska oil fields, but one well put down by the St. Elias Oil Co. in the Katalla field is all that was actually accomplished in 1922. Meanwhile the project for work in the Cold Bay field, on Alaska Peninsula, was actively pushed, and drilling began in the winter of 1922–23.

In August, 1922, two steamers landed equipment for drilling at Portage Bay, in the Cold Bay field. The town of Kanatak, at the head of Portage Bay, was changed within a short time from a settlement of 10 or 15 whites to a boom town with tents, cabins, and frame buildings numbering a hundred or more and with a population of

150 to 200, which has been augmented by still others arriving on every boat. Several months before the oil rigs were landed all the ground for several miles from the town had been staked. Drilling is to be done on the Pearl Creek dome, 17½ miles northeast of Kanatak, by the Associated Oil Co. and the Standard Oil Co. of California. The Associated Oil Co. has two portable Star rigs and intends to use local petroleum residue as fuel. The Standard Oil Co. has a standard rig and the equipment needed for drilling to a depth of 4,000 feet. Power is to be furnished by a 75-horse power gasoline engine. Immediately after the arrival of the steamers work was started on a wagon road that must cross two 1,000-foot divides, and by the middle of October this road was a little more than half completed. All hauling is being done by tractors. It is reported that the Associated Oil Co. had reached a depth of 200 feet in March, 1923, and that the Standard Oil Co. had started drilling about March 1.

The work in the Cold Bay oil field is by far the most important event in the history of the Alaska petroleum lands since they were thrown open to leasing in 1921. Though it was the only definite action taken in 1922 for drilling in the prospected though undeveloped Alaska oil lands, plans for such development in other parts of the Territory are under way, and applications for oil permits are still being filed. Test drilling in other regions will quickly follow the discovery of an oil pool in the Cold Bay field or may even precede it. The only oil produced in Alaska in 1922 was that obtained from the 11 small wells on the single patented tract in the Katalla field. These wells are owned by the Chilkat Oil Co., which finds a ready local market for its product in the form of gasoline produced at its own refinery.

It is known that there are good possibilities for the occurrence of a large oil field in the extreme northern part of Alaska. Some indications of oil have been found or reported in the Arctic coastal-plain region, in a belt some 400 miles in width, and what is known of the geology suggests that the geologic conditions may be favorable for petroleum. It will, however, take many years of surveys and investigations before any part of this vast and inaccessible region can be classed as probable oil land. If there is a large oil field in this region means will be found to develop it, but this will not be done under the restrictions imposed by the present petroleum-land leasing law. No such large investment as would be required by such a project will be made unless the conditions are so changed as to be very attractive to the investor.

In February, 1923, about 35,000 square miles of the western part of this possible oil-bearing region was withdrawn from entry as naval petroleum reserve No. 4. Alaskans, from bitter experience in the past, have a well-grounded prejudice against withdrawals. In this

case, however, the withdrawn area is of no value for development under the present land laws. The Executive order indicates the purpose of the reservation by the following clause: "Said lands to be so reserved for six years for classification, examination, and the preparation of plans for development," and until otherwise ordered by Congress or the President private interests in this region are safeguarded by the following clause: "The reservation hereby established shall be for oil and gas only and shall not interfere with the use of the lands or waters within the area indicated for any legal purpose in connection therewith." In April, 1923, the Navy Department made a grant to the Geological Survey to meet the cost of an investigation of a part of this reserve.

Petroleum products shipped to Alaska from other parts of the United States, 1905–1922, in gallons.[a]

Year.	Heavy oils, including crude oil, gas oil, residuum, etc.	Gasoline, including all lighter products of distillation.	Illuminating oil.	Lubricating oil.
1905	2,715,974	713,496	627,391	83,319
1906	2,688,940	580,978	568,033	83,992
1907	9,104,300	636,881	510,145	100,145
1908	11,891,375	939,424	566,598	94,542
1909	14,119,102	746,930	531,727	85,687
1910	19,143,091	788,154	620,972	104,512
1911	20,878,843	1,238,865	423,750	100,141
1912	15,523,555	2,736,739	672,176	154,565
1913	15,682,412	1,735,658	661,656	150,918
1914	18,601,384	2,878,723	731,146	191,876
1915	16,910,012	2,413,962	513,075	271,981
1916	23,555,811	2,844,801	732,369	373,046
1917	23,971,114	3,256,870	750,238	465,693
1918	24,379,566	1,086,852	382,186	362,413
1919	18,784,013	1,007,073	3,515,746	977,703
1920	21,981,569	1,764,302	887,942	412,107
1921	9,209,102	1,403,683	2,021,033	232,784
1922	15,441,542	1,436,050	2,095,675	345,400
Total	284,581,705	28,209,441	16,811,858	4,590,824

[a] Compiled from Monthly Summary of Foreign Commerce of the United States, 1905 to 1922, Bureau of Foreign and Domestic Commerce.

STRUCTURAL MATERIALS, ETC.

The mining of gypsum in the Sitka precinct continued on about the same scale as in previous years. In 1922 the output of the marble quarries of Prince of Wales Island, in the Ketchikan precinct, was larger than that of 1921. The sulphur mining and refining plant on Akun Island made no production during the year, and no graphite, barite, or garnet was produced.

REVIEW BY DISTRICTS.

The enormous extent of Alaska and its greatly diversified mining industry make it difficult to obtain complete records of important events in every one of the fifty-odd districts where productive mining is being carried on. The small technical staff assigned to the

Alaskan work of the Geological Survey under the present reduced appropriation can not reexamine these districts except at long intervals. Therefore, many of the data contained in the following review were of necessity gained by correspondence. If every miner in Alaska would report the results of his work, this summary could be made complete. Unfortunately this ideal has not been attained, and therefore the following statement is necessarily incomplete. As most of the mine operators can be reached by mail only once during the year, prompt publication demands that this report be prepared by the spring following the year which it covers. As a rule data received after that can not be included. The space here devoted to any one district may indicate the amount of information on hand relating to its mining developments rather than its relative importance.

SOUTHEASTERN ALASKA.

The mineral output of southeastern Alaska in 1922 was derived from seven gold and silver lode mines, one copper mine, a few small placer operations, a gypsum mine, and a group of large marble quarries. The value of the total mineral output decreased from $3,865,150 in 1921 to $3,084,389 in 1922. This decrease is largely due to the smaller production of the Ready Bullion mine, which was closed in December. During the year there were marked advances in gold-lode development in southeastern Alaska, especially in the Portland Canal region.

KETCHIKAN DISTRICT.

The Rush & Brown mine was the only producing copper mine in southeastern Alaska in 1922. Some work was done at the Jumbo copper mine, preparatory to reopening it, and some development work was done at the Lake Bay property. The Salt Chuck copper-palladium mine is in the hands of a receiver and made no production in 1922. No report was received from Julia gold mine, which was apparently closed. Developments were continued at the Fortuna mine, and some test shipments of gold ore were made. Some work was also done on the Alaska and Free Gold properties, at Helm Bay.

The large marble quarries near the north end of Prince of Wales Island were worked on a somewhat larger scale in 1922 than in previous years.

Mining near Hyder, in the Portland Canal region, consisted in the development of at least a dozen properties carrying chiefly gold, silver, and lead ores, with some other valuable minerals. No ore was produced, but some test shipments have been made. The aggregate amount of open cuts and drifts is large, and the results of

this work are reported to be exceedingly favorable. The development of shipping mines is soon to be expected. Information about the developments on individual properties of the district is not complete enough to justify a summary.

WRANGELL DISTRICT.

No productive mining was carried on during 1922 in the Wrangell district. The silver-lead ores are still being developed, it is said, with encouraging results. Application has been made for patent to the barite deposits on Castle Island, in Duncan Canal. There was no production and but little development of copper ore.

JUNEAU DISTRICT.

At Juneau mining interest centered on the remarkable results achieved in the milling of the ore of the Alaska Juneau mine. The mine is developed by a 7,000-foot adit and equipped with a concentrating mill having a daily capacity of 8,000 tons. Up to the end of 1922 the total underground developments, exclusive of stopes, aggregated 111,273 feet. The work done in 1922 comprised drifts and crosscuts, 1,071 feet; raises, 2,291 feet; interdrifts, 172 feet; powder drifts, 1,907 feet; bulldozing chambers, 60 feet; stations, 52 feet—a total of 5,553 feet.

Production of Alaska Juneau mine, 1921–22 and 1893–1922.

	Ore (tons).			Metals recovered.			
	Total.	Fine or milled.	Coarse tailings rejected.	Gold.	Silver (ounces).	Lead (pounds).	Total value.
1921	1,613,600	904,323	709,277	$969,703	40,619	550,913	$1,035,251
1922	2,310,550	1,108,559	1,201,991	1,296,157	49,405	687,314	1,388,679
1893–1922	7,752,549	5,263,523	2,489,026	5,431,526	162,914	2,833,139	5,768,580

The Ready Bullion mine and 100-stamp mill were operated throughout the year until December 20, when both were permanently closed. During the summer a little groundsluicing was done at a placer mine in Silver Bow Basin.

The Peterson gold mine, north of Juneau, which has been worked in a small way for many years, was closed during 1922. The Daisy Bell, a small mine south of Juneau, was also closed.

The Jualin mine, at Berners Bay, north of Juneau, which was closed in 1917 because of war conditions, is now under lease to the Jualin Berners Mining Co. This company in 1922 continued the old drainage tunnel and employed some 45 men. During the last years of operations, 1915 and 1917, the mine milled 25,691 tons of ore with

an average recovery of $10.81 a ton, giving an extraction of 91 per cent of the assay value.

No report has been received from the Endicott Mining & Milling Co., which is opening a lode property on William Henry Bay, on the west side of Lynn Canal. According to newspaper statements, the 15-stamp mill was completed in November and started operations before the end of the year.

SITKA DISTRICT.

Productive mining in the Sitka district includes the work done at Chichagof and Hirst-Chichagof gold mines, in the northern part of Chichagof Island, and the gypsum mine at Iyoukeen Cove, on the east shore of the island. In 1922, as in the past, the Chichagof was the only large producing mine. Here the underground work during the year consisted of 320 feet of shafts and 2,060 feet of drifts. The total developments to date are reported to comprise 1,570 feet of shafts, 18,680 feet of drifts, and 10,000 feet of adits (six).

No report has been received from the Hirst-Chichagof mine. It is known, however, that the erection of a 10-stamp mill was completed, and the mill started operations during the summer. The prospecting of nickel-bearing copper ores in the northwestern part of Chichagof Island is reported as being continued. The Pinta Bay Mining Co. continued the development of its gold property on Chichagof Island, and toward the end of the year was preparing to install a mill. In the same district the Falcon Bay Co. also continued work on a gold property and completed 640 feet of adit. At the Brown Bear group 140 feet of underground work has been completed, chiefly in 1922. At the Golden Copper group development work was continued during the year, and a small mill has been installed. At the El Nido property, on Lisianski Inlet, the ore lode is reported to have been found in the lowest crosscut, 475 feet below the outcrop of the vein.

OTHER DISTRICTS.

The development of gold placer mines on Porcupine, McKinley, and Cahoon creeks, in the Porcupine district of southeastern Alaska, continued in 1922. It is planned to exploit the placers on these three creeks by two large hydraulic elevator plants. The most important developments of the year were the building of a bridge across Porcupine Creek and the extension of a road up the same creek. Some work was also done on the Porcupine property, an auriferous lode. About 30 men are reported to have been employed in this development work.

No reports have been received from the Lituya Bay region, but it is believed that a little placer mining was done there.

Five men were engaged in mining the beach placers of Yakataga during the season of 1922, which extended from about May to December. The actual working time of these mines was between 60 and 150 days, and the work was done by groundsluicing. It is reported that good placer prospects have been found away from the beach in spruce timber. The geologic information at hand indicates a recent elevation of the shore line. If this is true, the discovery of ancient beach deposits is not improbable.

COPPER RIVER BASIN.

The continuous operation of the three large copper mines of the Kennecott group and the summer placer mining in the Nizina and Chistochina districts constitute nearly all the productive work done in the Copper River basin in 1922.

In the west end of Chitina Valley [5] some mining operations were conducted on Elliott Creek and on Berg Creek, tributary to Kuskulana River. The work at the North Midas mine, on Berg Creek, was done by an association called the "Engineer syndicate." The small cyanide plant installed near the mouth of Berg Creek was replaced by a flotation plant, and the gold and silver bearing pyrite of the ore was concentrated to a shipping product for smelter treatment. The concentrates were hauled by a tractor nearly 12 miles from the mill to Strelna and shipped on the Copper River & Northwestern Railway. A semi-Diesel engine was installed in the summer of 1922 as a source of auxiliary power to that obtained from Berg Creek.

Development work on the copper prospects of Elliott Creek was directed principally toward the exploration of the Goodyear and Henry Prather claims, on Rainbow Creek, and the "Kings claims," near the head of Elliott Creek. The principal camp is now at the mouth of Rainbow Creek, but a new camp was established at the head of the Elliott Creek valley, and from these two camps as bases exploratory tunnels were driven on the claims mentioned. Power for the compressors was furnished by two semi-Diesel engines, and supplies were freighted by pack train from Strelna.

The mines at Kennicott, including the Bonanza, Jumbo, and Mother Lode, were steady producers of copper throughout the year. Although the Mother Lode mine is operated by the Kennecott Corporation as a separate project, its ore is now brought to the surface through the Bonanza mine and is sent to the mill over the Bonanza tram. These mines are remarkable because of the high grade of the ore, which consists principally of chalcocite and carbonates, and the low cost of producing copper. Development has now been carried down to the 1,500-foot level, and nothing has been found to indicate how much deeper the ore bodies may be expected to extend.

[5] Notes by F. H. Moffit.

During the summer the steam turbines that have heretofore furnished power for all mine operations were supplemented by two new Diesel engines capable of bearing all the load. This improvement will result in a very material saving in the cost of fuel oil and should lead to a further decrease in the cost of producing copper.

The following statements on mining and milling at the Kennecott group of mines during 1922 are taken from the annual report of the company:[6]

Kennecott ores milled totaled 182,726 tons, assaying 6.47 per cent. From this tonnage there was produced 18,277 tons of concentrates of an average assay of 49.63 per cent copper. * * * The leading plant treated 217,395 tons of mill tailings assaying 90 per cent carbonate copper, producing 1,976.78 tons of precipitates, containing, 2,970,400 pounds of copper. The development work done at Kennecott during the year totaled 7,893 feet, as well as 6,637 feet of diamond drilling. At the Erie mines work was started on a crosscut 12,000 feet long, which will connect with the Jumbo mine.

The Mother Lode mine, adjacent to the Kennecott-Bonanza, is worked by the same company. Its ore is treated in the Kennecott mill. The Mother Lode is developed by an 850-foot adit and a 700-foot shaft.

Possibly the most important new development of the year in the Nizina district viewed from the standpoint of its potential benefit to the district generally, is the work at the Green group, on McCarthy Creek, about 11 miles from the town of McCarthy. A promising body of chalcocite was discovered in the limestone at the limestone-greenstone contact on the east side of McCarthy Creek, at a point on the hill slope where the contact was covered by slide rock. A tunnel was started at this point and extended into the limestone. Another tunnel was driven through the greenstone to the limestone 100 feet lower than the first tunnel, and a raise was made to connect the two. Copper deposits were found in the greenstone, but the principal ore body was encountered in the limestone of the upper tunnel and in the raise. Exploration had not advanced sufficiently at the time this property was visited to determine whether the ore body is large enough to yield a mine.

In the Nizina placer district two large hydraulic plants were operated in both Dan and Chititu creeks, and there were some smaller summer operations on Rex and Young creeks. A little winter mining was also done on Rex and Dan creeks, and some prospecting on Copper Creek. A total of eight mines, employing 98 men, were operated in the Nizina district in the summer of 1922, and three mines, employing 5 men, during the preceding winter.

Hydraulic mining in the bench gravel on the north side of Dan Creek resulted in the discovery that the creek, at some earlier time in its history, had cut one or more terraces in the shale bedrock, so that the overburden has proved to be less than the topography seemed to indicate, and the work of removing it will therefore be less than was expected. Mining on Dan Creek has been carried on chiefly in the stream gravel, and comparatively little attention has been given to the bench gravel, although it is known to be gold bearing. Placer mining on Chititu Creek in 1922 was done under

---

[6] Kennecott Copper Corporation Eighth Ann. Rept., for 1922, pp. 5–6, New York, 1923.

difficulties because of differences between the operators and laborers and because of unseasonable weather, so that probably a diminished output was made. At the time when the first snow came, late in August, work on the cuts laid out for the season was much less advanced than is ordinarily expected at that time of the year. On Young Creek considerable prospecting and some mining was done in the summer, with results sufficiently good to encourage the miners to continue their work another season.

In the Chistochina district the hydraulic plant on Slate Creek, employing 25 men, was much the largest in operation. One plant employing 10 men was also operated on the Middle Fork of the Chistochina, and there were probably other small mining activities that were not reported.

The unusually dry season in the Nelchina district, in the western part of the Copper River basin, seriously interfered with placer mining and almost no gold was produced there. The Alaska Placer Gold Mining Co., on Alfred Creek, made the largest developments. It built a mile of ditch and a 400-foot flume and installed a hydraulic plant. One other small mine was worked on Alfred Creek and three others on Albert Creek. The value of the placer gold mined in the Copper River basin during 1922 was about $165,000.

PRINCE WILLIAM SOUND.

In 1922 the only output of minerals on Prince William Sound was that made at the Beatson copper mine and at the Big Four, Gold King, and Ramsay-Rutherford gold mines, near Valdez. There was, however, in the aggregate considerable prospecting of lode deposits. According to the Kennecott Copper Corporation,[7] the Latouche property (Beatson-Bonanza) was operated at approximately 50 per cent capacity throughout the year. The mill treated 274,863 tons of ore assaying 1.88 per cent copper, producing 23,147 tons of concentrates assaying 18.99 per cent copper.

A total of 7,155 feet of development work was done at Latouche during the year.

No report has been received from the Girdwood mine, adjacent to the Beatson-Bonanza, which appears to have been idle. Statements have been published in the press that this property was purchased in 1923 by the Kennecott Corporation.

Outside of the work at the Beatson-Bonanza mine, the most important developments on the sound have been made at the Rua copper property, on Knight Island. This mine is now developed by a drift 900 feet long and a total of 750 feet of crosscuts. The crosscuts are spaced at 100-foot intervals. In 1922 244 feet of underground work

[7] Kennecott Copper Corporation Eighth Ann. Rept., 1922, p. 6, New York, 1923.

was done. Drifts and crosscuts are about 1,500 feet below the highest outcrop of the ore body.

In the description of this ore body published by the Geological Survey it is stated [8] that at an altitude of 750 feet the ore body "pinches out beneath overlying greenstone flows," but this statement has been found to be erroneous. In fact, some evidence of the fissure and of copper mineralization is traceable to the top of the cliff, 1,500 feet above the mine workings.

The continued low price of copper has discouraged the development of copper lodes on the sound, and little was done except assessment work. At the Fidalgo mine a 30-foot adit was driven, and there were minor operations on other properties.

The Big Four gold mine, near Valdez, was operated for a part of the summer. It is developed by drifts and crosscuts and equipped with a small prospecting mill, and an aerial tram is to be built. The Gold King, also in the Valdez district, developed by adits and shafts and equipped with a prospecting mill, was further developed during the summer. No report was received from the Ramsay & Rutherford mine, in the same district. It appears, however, that some gold was produced in this mine in the early part of 1922, though this may have resulted from work done in the preceding year. The Culross mine, in the western part of Prince William Sound, was reopened about midsummer of 1922. An air compressor and drills were installed, and the old 400-foot adit was enlarged and regraded, and the face advanced 160 feet. Plans for a new mill were made, with the expectation of operations in 1923. Only assessment work is reported on the other gold lodes of Prince William Sound.

KENAI PENINSULA.

Only five placer mines were reported to have been operated on Kenai Peninsula and in the adjacent region during 1922, but there is some evidence that about 12 mines made more or less gold output. The apparent failure of more than half the mine operators to furnish reports makes it impossible to give anything but estimates of output, but it is believed that about $40,000 worth of gold was produced.

The largest placer mine in this region is on Crow Creek, where a hydraulic plant was operated from June 5 to October 4, employing 16 men. This is the only large operation in the region, but some others are being prepared. The largest number of producers was on Resurrection Creek, but productive mining was also done on Mills, Lynx, Canyon, and Bear creeks.

The Lucky Strike gold quartz mine and mill were operated from the end of May to October. Underground developments consist of a

[8] Johnson, B. L., Copper deposits of the Latouche and Knight Island districts, Prince William Sound: U. S. Geol. Survey Bull. 662, p. 214, 1918.

300-foot adit, of which 165 feet was driven in 1922. A 5-stamp mill was installed on Kenai Star late in the summer and is believed to have been operated for a part of the season. Work was continued at the Jewel mine, north of Turnagain Arm, and some ore was crushed in the 10-stamp mill. Work was also continued at the Strong gold quartz property, in the same general region. Some underground development work was done during the year at the Grant Lake mine, but there was no production. So far as known, the only other mining on the peninsula was the operation during the summer of the McNally & Maitland lignitic coal mine, on Kachemak Bay (p. 20).

SUSITNA-MATANUSKA REGION.

Productive mining in the Susitna-Matanuska region included gold-lode mining in the Willow Creek district, gold-placer mining in the Yentna district and at a few scattered localities, bituminous-coal mining in the Matanuska field, and a little lignite mining at a number of scattered localities in the Susitna basin. (See p. 20.) The value of the total mineral production from this region was $677,025 in 1921 and $803,685 in 1922.

WILLOW CREEK DISTRICT.[9]

Productive gold mining was done on seven lode mines in the Willow Creek district. The largest output came from the Gold Bullion and Lucky Shot mines, controlled by the Willow Creek Mining Co. The Lucky Shot mine and mill were operated throughout the year. About 450 feet of drifts and 225 feet of adits have been driven. The mine is equipped with an 8-stamp mill. A 930-foot adit has been started which crosscuts the ore body 450 feet below the highest level, and a 50-ton cyanide plant is to be installed.

The same company is developing the adjacent War Baby mine, where a crosscut tunnel has been driven and some drifting done along the vein. An aerial tram has been built.

In 1922, as for many years, the Gold Bullion mine and mill, using water power, were operated during the open season. The mine is developed by 500 feet of adits and equipped with a 12-stamp mill, a classifying and amalgamation plant, and a 50-ton cyaniding plant.

The Kelly Mines Co. controls a group of auriferous properties lying in the basins of Fishhook and Willow creeks. These properties include the Brooklyn, Independent, Free Gold, and others. Among them are some gold mines that have been productively worked in the past in a small way. In 1922 the company undertook a much deeper testing of the veins, which had been developed only to a shallow depth. After a careful survey it was decided to drive a crosscut tunnel beneath the veins developed on the Willow-Fishhook divide. This long crosscut is now under way.

[9] In part based on information from Philip S. Smith.

A long crosscut was being driven at the Rae-Wallace property during the summer of 1922. The small mill was operated only intermittently.

Work was continued at the Gold Mint (Hatcher) mine, and the mill was run 22 days. Here a 20-foot shaft, a 300-foot adit, a 58-foot crosscut, and a 58-foot raise have been completed.

The Fern mine, on Archangel Creek, was operated throughout the year. A 520-foot drift that had been driven prior to 1922 was repaired during the year and extended 178 feet. A Dease mill, having a capacity of 30 tons, was installed November 15 and operated the rest of the year.

At the Consolidated (Talkeetna) property, on Fairangel Creek, development work was continued. During the year the mill on this property was used only for testing the ore derived from the development work.

Some developments were continued at the Mabel mine, and the mill was used in test runs on the ore recovered incidentally to this mining.

Development work was continued during the year at the Opal (Skarstad), Home Builder (Richter), Webfoot (Conroy), Homesteader-Martha, and many other properties from which there was no production, and assessment work was done on many claims. The success of several mines in the district and the projects for systematic work under way give great hopes for the future.

Gold and silver produced at lode mines in the Willow Creek district, 1908–1922.

Year.	Mines operated.	Ore mined (short tons).	Gold.		Silver.	
			Ounces.	Value.	Ounces.	Value.
1908	1	12	87.08	$1,800	6.88	$3.64
1909	1	140	1,015.87	21,000	80.25	41.73
1910	1	144	1,320.15	21,290	104.29	56.31
1911	2	812	2,505.82	51,800	197.95	109.91
1912	3	3,000	4,673.02	96,600	369.07	226.97
1913	3	3,028	4,883.94	100,960	385.83	233.42
1914	3	10,110	14,376.28	297,184	1,330.00	735.00
1915	3	6,117	11,961.55	247,267	811.00	421.00
1916	3	12,182	14,473.46	299,193	1,468.00	967.00
1917	5	7,885	9,466.17	195,662	713.00	586.00
1918	5	13,043	13,043.05	269,624	724.00	724.00
1919	5	6,730	7,882.00	162,944	508.00	509.00
1920	3	2,850	3,067.00	63,400	148.00	158.00
1921	7	3,591	5,721.50	118,273	1,029.00	1,029.00
1922	7	7,242	11,513.25	238,000	1,500.00	1,500.00
	....	76,886	105,990.14	2,184,997	9,375.27	7,300.98

YENTNA DISTRICT.

Mining was very successful in the Yentna district in 1922. Most of the gold produced came from the dredge on Cache Creek, which was operated on a larger scale than ever before, and from hydraulic

plants; some was obtained from pick and shovel mines. Altogether there were productive placers in the district employing about 96 men. This district contains no deep placers suitable for winter exploitation. In all, 471,986 cubic yards of gravel was mined and sluiced during the year, with an average gold recovery of 44 cents to the cubic yard. In 1921 a total of $120,000 worth of gold was mined and in 1922 $223,000 worth. No platinum was reported by any of the placer miners of the district.

The occurrence of gold-bearing quartz veins in the Yentna district has long been known, but so far no auriferous lodes of commercial value have been developed. Mertie[10] described some apparently detrital deposits of auriferous quartz on Thunder Creek. Miners report that what may be an extension of the same zone of metallization has been traced through Dollar, Falls, and Thunder creeks.

OTHER DISTRICTS.

Some placer gold has been found on Metal Creek, a tributary of Knik River, southeast of the town of Anchorage. The development of a group of claims was under way during 1922, and a little gold was recovered incidentally. There was in the aggregate much prospecting of gold and copper lode claims in the region tributary to the railroad above Willow Creek. This region includes what are generally called the Talkeetna or Iron Creek, the Chulitna, and the Broad Pass districts. There has also been a little placer mining in this region, though no reports from miners have been received. A little lignitic coal was mined in this region for local use.

Only one placer mine in the Valdez Creek district reported in 1922, though it is believed that three or four were operated. One large hydraulic plant on Valdez Creek is known to have been operated, but the company made no report.

The Nelchina district is tributary to the Alaska Railroad but lies on Copper River and is described on page 28.

SOUTHWESTERN ALASKA.

The outstanding event of the year in southwestern Alaska was the continued activity in staking oil claims and preparations for drilling, as already noted (pp. 20–21). The importance of the outcome of this drilling can scarcely be overestimated, for the bringing in of a productive oil field would immediately insure a thorough investigation of all possible oil-bearing territory and would stimulate drilling in many places. In the Lake Iliamna region placer mining was practically discontinued and lode prospecting was prosecuted on only a small scale. There was no production reported. Underground

[10] Mertie, J. B., jr., Platinum-bearing gold placers of the Kahiltna Valley: U. S. Geol. Survey Bull. 692, pp. 250–251, 1919.

development work was continued on the Duryea copper claim and some work on trails was done in order to make it possible to ship out some ore.

A few men were engaged in beach placer mining at the south end of Kodiak Island and on the adjacent Trinity Islands, but conditions were unfavorable for beach mining in this vicinity in 1922 and the production was small. A little prospecting was done on quartz veins on Kodiak Island.

At the Apollo mine, on Unga Island, some experimental work was done, and a small quantity of ore was mined and concentrated; the concentrates were shipped to the smelter, and a small amount of gold and copper was recovered.

No sulphur was produced at the plant on Akun Island during the year.

YUKON BASIN.

GENERAL FEATURES.

The value of the total mineral output of the Alaska Yukon region in 1922 was $2,303,755, as compared with $2,093,088 in 1921. This brings the total value of the mineral products of the Alaska Yukon during 37 years of mining to $137,580,598.

Mineral production of the Yukon basin, Alaska, in 1922.

	Placer mines.		Lode mines.		Total.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Gold..............fine ounces..	102,507	$2,119,000	2,874	$59,415	105,381	$2,178,415
Silver......................do....	13,751	13,751	9,070	9,070	22,821	22,821
Coal......................tons..					23,636	97,292
Lead, copper, and tin..........						5,227
	....	2,132,751	....	68,485	....	2,303,755

Mineral production of the Yukon basin, Alaska, 1886–1922.

	Placer mines.		Lode mines.		Total.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Gold..............fine ounces..	6,498,342	$134,331,000	65,673	$1,357,090	6,564,015	$135,688,090
Silver......................do....	1,109,150	682,093	246,861	248,787	1,356,011	930,880
Coal......................tons..					81,071	416,845
Lead, copper, tin, antimony, tungsten, and platinum......						544,783
	....	135,013,093	....	1,605,877	....	137,580,598

In the summer of 1922 about 321 placer mines, employing 1,254 men, were operated in the Alaska Yukon, and during the preceding winter about 99 mines, employing 321 men. The only other productive mining in this region in 1922 was done at 8 lode mines,

employing about 50 men, and 2 coal mines, employing about 38 men. None of these mines were operated throughout the year.

Estimated value of gold produced from principal placers of Yukon basin in 1922.

Fairbanks	$693,000	Chandalar	$83,000
Iditarod	280,000	Hot Springs	55,000
Innoko and Tolstoi	224,000	Fortymile	50,000
Tolovana	221,000	All others	137,000
Koyukuk	132,000		
Ruby	123,000		2,119,000
Circle	121,000		

FAIRBANKS DISTRICT.

In the Fairbanks district placer and lode mining was continued on a somewhat larger scale than in 1921. The value of the total mineral output of the district during 20 years of mining is $74,015,674. Some antimony, tungsten, and lead have been produced in this district, but, as shown in the following table, the mineral output has come briefly from the placer mines.

Placer gold and silver produced in the Fairbanks district, 1903–1922.

Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.
1903	1,935.00	$40,000	348	$188
1904	29,025.00	600,000	5,225	2,821
1905	290,250.00	6,000,000	52,245	28,212
1906	435,375.00	9,000,000	78,367	42,318
1907	387,000.00	8,000,000	69,660	37,616
1908	445,050.00	9,200,000	79,909	43,151
1909	466,818.75	9,650,000	84,027	45,375
1910	295,087.50	6,100,000	53,116	28,683
1911	217,687.50	4,500,000	52,245	27,690
1912	200,756.25	4,150,000	48,182	29,632
1913	159,637.50	3,300,000	20,274	12,245
1914	120,937.50	2,500,000	29,024	16,050
1915	118,518.75	2,450,000	28,444	14,421
1916	87,075.00	1,800,000	11,058	7,276
1917	63,371.25	1,310,000	8,379	6,904
1918	38,700.00	800,000	5,708	5,708
1919	35,313.75	730,000	5,197	5,820
1920	28,057.50	580,000	3,870	4,218
1921	27,573.75	570,000	3,941	3,941
1922	33,523.87	693,000	4,783	4,783
Total	3,481,693.87	71,973,000	644,002	367,053

The placer output of 1922 came from 62 placer mines, employing 392 men, in the summer and 27 mines, employing 108 men, during the preceding winter. In 1921 work was done at 48 summer mines, employing 340 men, and 14 winter mines, employing 107 men. A total of 516,422 cubic yards of gravel was sluiced in 1922, having an average gold content of about $1.34 to the cubic yard. The placer mines comprised 45 drift mines, of which 25 were operated in the winter as well as in summer and 10 only in winter, 2 dredges, 10

open-cut mines using steam scrapers, 5 hydraulic mines, and 11 small open-cut mines without any special mechanical equipment. The drift mines sluiced about 56,000 cubic yards of gravel carrying $4.55 worth of gold to the cubic yard. Some 460,000 cubic yards of gravel was sluiced from the open-cut mines and dredges. The gold recovery from this gravel was about 95 cents to the cubic yard. The sluicing season averaged about 126 days.

The largest single drift-mining operation was on Little Eldorado Creek, and the two dredges on Fairbanks Creek were the largest open-cut plants. On Cleary Creek, formerly the largest producer of placer gold in the district, only eight mines, most of them small, were in operation in 1922. A dredging company, however, has obtained options on a large number of claims on Cleary Creek and in Chatanika Valley near the mouth of Cleary Creek and during 1922 employed three Keystone drills, working two shifts, for about six months in prospecting the ground preliminary to dredging. In the Goldstream Creek basin 23 placer mines, large and small, were operated in 1922. One operator in the district reports that the cost of provisions has dropped 30 per cent since 1918, and the opening of the Alaska Railroad should still further reduce working costs. This will stimulate mining on many properties that have been operating on a narrow margin of profit.

Approximate distribution of placer gold produced in Fairbanks district, 1903–1922, by sources.

Cleary Creek and tributaries	$23,198,000
Goldstream Creek and tributaries	15,085,000
Ester and adjacent creeks	11,443,000
Dome and Fairbanks creeks	16,486,000
Vault Creek and tributaries	2,701,000
Little Eldorado Creek	2,360,000
All other creeks	700,000
	71,973,000

The production of the lode mines in the Fairbanks district in 1922 showed a gratifying increase over that in 1921, being in fact larger than in any other year since 1915. Active mining was conducted on five properties, and prospecting and development work on a number of others. At the Mohawk mine, on Ester Creek, a tunnel 150 feet long was driven from the creek level to tap the ore body at depth. The ore mined was milled at the custom mill on Eva Creek. At the Hi Yu mine work was continued and the ore treated at the 5-stamp mill on the property. The Smith Bros., at their mine on the St. Patrick's Creek divide, are reported to have struck the ledge toward which they had been sinking at the 200-foot level. The ore is said to have yielded satisfactory returns, and a pump was to be installed in the spring of 1923 to handle the water in the main shaft. No tungsten was mined in the Fairbanks district in 1922.

Lode gold and silver produced in the Fairbanks district, 1910–1922.

Year.	Crude ore (short tons).	Gold.		Silver.	
		Fine ounces.	Value.	Fine ounces.	Value.
1910	148	841.19	$17,389	106	$57
1911	875	3,103.02	64,145	582	308
1912	4,708	9,416.54	394,657	1,578	971
1913	12,237	16,904.98	349,457	4,124	2,491
1914	6,526	10,904.75	225,421	2,209	1,222
1915	5,845	10,534.91	217,776	1,796	910
1916	1,111	1,904.81	39,376	140	92
1917	1,200	2,311.38	47,781	2,217	1,826
1918	1,035	1,294.04	26,750	616	656
1919	1,384	2,026.57	41,893	378	424
1920	504	967.48	20,000	164	178
1921	944	1,858.27	38,414	279	279
1922	1,724	2,612.25	54,000	490	490
	38,241	64,680.19	1,337,059	14,679	9,864

HOT SPRINGS DISTRICT.

Placer mining has been on the decline in the Hot Springs district for several years, the annual production having shrunk from $800,000 in 1916 to $35,000 in 1921. In 1922 production increased somewhat, and this may be the beginning of more prosperous times in the district, for freight costs have been reduced since the building of the Alaska Railroad, and it should now be possible to exploit many properties at a profit that have not been rich enough to be workable under the existing heavy overhead charges. In all, 25 mines were operated in 1922, of which 18 produced more than $1,000 worth of gold each. About 60 men were employed in summer and about 10 in winter mining. Considerably more gold was produced by open-cut mining than by drift mining, and with the increase of hydraulic operations the proportion of gold recovered in this way is likely to show a still further increase.

Placer gold and silver produced in the Hot Springs district, 1902–1922.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1902–3	12,717.79	$262,900	1,818	$964	1914	36,281.25	$750,000	6,125	$3,387
1904	7,038.56	145,500	1,007	584	1915	29,508.75	610,000	4,982	2,526
1905	5,805.00	120,000	831	507	1916	38,700.00	800,000	6,534	4,299
1906	8,707.50	180,000	1,245	843	1917	21,768.75	450,000	3,675	3,028
1907	8,465.63	175,000	1,210	798	1918	7,256.25	150,000	1,225	1,225
1908	7,256.25	150,000	1,038	550	1919	4,837.50	100,000	817	915
1909	15,721.88	325,000	2,248	1,169	1920	2,418.75	50,000	567	618
1910	15,721.88	325,000	2,248	1,169	1921	1,693.12	35,000	438	438
1911	37,974.37	785,000	5,430	2,932	1922	2,660.62	55,000	631	631
1912	19,350.00	400,000	3,267	2,009					
1913	19,350.00	400,000	3,267	1,973		303,233.85	6,268,400	48,603	30,565

TOLOVANA DISTRICT.

In the Tolovana district about 25 mines in all were operated in 1922, employing approximately 132 men in open-cut mining and 60 in drift mining. The gold production, as shown in the subjoined table, was somewhat less than in 1921. An unusually heavy rainfall during the summer of 1922 favored placer mining, yet because of the gradual depletion of the ground fewer mines were operated and the production consequently decreased. Livengood Creek, as usual, produced a large part of the total production for the district; Amy and Olive creeks followed in the order named. The discovery on Wilbur Creek, made in 1921, proved to be somewhat disappointing, as the gold content was low and the pay streak narrow. This creek will be mined by open-cut methods in 1923. Prospecting in this district has been continued and some ground found that will be mined in 1923.

Placer gold and silver produced in the Tolovana district, 1915–1922.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1915	3,870.00	$80,000	321	$163	1920	9,675.00	$200,000	819	$893
1916	33,862.50	700,000	2,813	1,851	1921	13,786.88	285,000	1,189	1,189
1917	55,631.25	1,150,000	8,430	6,946	1922	10,690.88	221,000	913	913
1918	42,328.12	875,000	4,060	4,060					
1919	25,396.88	525,000	2,141	2,454		195,241.51	4,036,000	20,686	18,469

RAMPART DISTRICT.

The production of gold from the Rampart district in 1922 was slightly less than in 1921. About 14 properties were operated, employing about 25 men in summer and 4 in winter. As usual, the largest production came from Little Minook Creek. The chief event of interest in this district in 1922 was the preparation by the Rampart Gold Mining Co. to install a dredge on Minook Creek. The dredge was in transit during the summer and was expected to arrive before the freeze-up. It was planned to erect the dredge and have it ready for operation in the summer of 1923.

Placer gold and silver produced in the Rampart district, 1896–1922.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1896–1903	[a]29,799.00	$616,000	4,440	$2,664	1914	1,451.25	$30,000	257	$142
1904	4,353.75	90,000	649	376	1915	1,693.13	35,000	300	152
1905	3,870.00	80,000	576	351	1916	1,935.00	40,000	343	226
1906	5,805.00	120,000	865	588	1917	1,644.74	34,000	283	233
1907	6,046.87	125,000	901	595	1918	1,209.37	25,000	215	215
1908	3,628.12	75,000	540	286	1919	1,596.37	33,000	115	129
1909	4,837.50	100,000	721	375	1920	1,015.88	21,000	80	87
1910	2,080.12	43,000	310	167	1921	1,064.25	22,000	95	95
1911	1,548.00	32,000	231	125	1922	870.75	18,000	62	62
1912	1,548.00	32,000	274	169					
1913	1,548.00	32,000	274	165		[a]77,545.10	1,603,000	11,531	7,202

[a] Includes small production from Gold Hill district.

CIRCLE DISTRICT.

During 1922 mining was continued in the Circle district on a somewhat larger scale than in the preceding two years. The largest output of any single plant was made by the dredge on Mastodon Creek. Fifteen summer mines, employing 42 men, and 8 winter mines, employing 16 men, were operated, handling over 260,000 yards of ground, with an average gold content of 46 cents to the yard. This low average gold content for all mines is of course due to the low grade of the ground worked by the dredge. Two promising new discoveries of placer ground in this district are reported, one by Lee and McGregor on Dome Creek and another in the Crazy Mountains.

Placer gold and silver produced in the Circle district, 1894–1922.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1894	483.75	$10,000	123	$77	1910	10,884.37	$225,000	2,830	$1,528
1895	7,256.25	150,000	1,886	1,226	1911	16,931.25	350,000	4,402	2,333
1896	33,862.50	700,000	8,794	6,080	1912	15,721.87	325,000	2,439	1,500
1897	24,187.50	500,000	6,289	3,773	1913	8,465.63	175,000	1,314	794
1898	19,350.00	400,000	5,031	2,968	1914	10,884.37	225,000	1,689	934
1899	12,093.75	250,000	3,144	1,886	1915	11,126.25	230,000	1,727	875
1900	12,093.75	250,000	1,886	3,144	1916	14,512.50	300,000	2,252	1,482
1901	9,675.00	200,000	2,512	1,507	1917	9,675.00	200,000	1,561	1,285
1902	9,675.00	200,000	2,512	1,331	1918	8,465.63	175,000	1,798	1,798
1903	9,675.00	200,000	3,144	1,698	1919	6,530.63	135,000	1,260	1,411
1904	9,675.00	200,000	3,144	1,823	1920	2,660.62	55,000	464	506
1905	9,675.00	200,000	3,144	1,918	1921	2,902.50	60,000	571	571
1906	14,512.50	300,000	3,773	2,565	1922	5,853.37	121,000	1,037	1,037
1907	9,675.00	200,000	3,144	2,075					
1908	8,465.63	175,000	2,212	1,166		325,853.99	6,736,000	78,170	49,505
1909	10,884.37	225,000	2,830	1,472					

RICHARDSON DISTRICT.

Prospecting was continued in 1922 in the Richardson district, and a small amount of gold was produced, though no mines were regularly operated. Many streams in this district yield coarse gold to the prospector's pan, and persistent and intelligent search may at any time prove the presence of workable ground. Indications were found in 1922 on Savage Gulch and Mineral Creek that were sufficiently favorable to warrant further investigation.

Placer gold and silver produced in the Richardson district, 1905–1922.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1905	(a)	(a)	(a)	(a)	1915	4,595.62	$95,000	939	$476
1906	4,837.50	$100,000	989	$673	1916	3,870.00	80,000	790	520
1907	18,140.62	375,000	3,707	2,447	1917	1,289.37	25,000	245	202
1908	18,140.62	375,000	3,707	1,965	1918	290.25	6,000	59	59
1909	7,256.25	150,000	1,483	771	1919	483.75	10,000	99	111
1910	4,837.50	100,000	989	534	1920	338.62	7,000	69	75
1911	4,837.50	100,000	989	524	1921	145.13	3,000	26	26
1912	4,837.50	100,000	989	608	1922	96.75	2,000	21	21
1913	4,837.50	100,000	989	597					
1914	4,837.50	100,000	989	547		83,971.98	1,728,000	17,079	10,156

a Prospects.

EAGLE AND SEVENTYMILE DISTRICTS.

In the Eagle district 14 summer mines were operated in 1922, employing 28 men and yielding a somewhat larger output of gold than in the preceding three years. As usual, the largest producing mines were the hydraulic mines on Crooked and Alder creeks. The upper basin of Seventymile River experienced an unusually dry season, which affected the gold production unfavorably.

Placer gold and silver produced in the Eagle and Seventymile districts, 1908–1922.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1908	483.75	$10,000	76	$40	1917	628.88	$13,000	96	$75
1909	1,209.37	25,000	191	99	1918	1,209.37	25,000	191	191
1910	483.75	10,000	76	41	1919	969.50	20,000	152	170
1911	580.50	12,000	92	49	1920	725.62	15,000	99	108
1912	967.50	20,000	164	100	1921	774.00	16,000	93	93
1913	2,418.75	50,000	382	231	1922	1,161.00	24,000	159	159
1914	2,418.75	50,000	382	211					
1915	1,935.00	40,000	305	155		16,788.11	347,000	2,588	1,808
1916	822.37	17,000	130	86					

FORTYMILE DISTRICT.

During 1922 mining was continued in the Fortymile district on about the same scale as in the past, 24 summer mines, employing 52 men, and 18 winter mines, employing 33 men, being operated. Most of these mines are small, as the average number of miners employed was about 2 to the mine. About 35,927 cubic yards of gravel was handled, carrying an average gold content of $1.39 to the yard. The greater part of the production was made by a few outfits, most of which employed scrapers. An attempt at hydraulic mining on Wade Creek was abandoned on account of lack of water, and scrapers were resorted to. As usual, a small amount of gold was recovered by individuals working the bars of Fortymile River.

Placer gold and silver produced in the Fortymile district, 1886–1922.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1886–1903	193,500.00	$4,000,000	30,553	$22,915	1914	2,418.75	$50,000	382	$211
1904	14,851.12	307,000	2,345	1,360	1915	2,418.75	50,000	382	194
1905	12,384.00	256,000	1,955	1,193	1916	2,418.75	50,000	382	251
1906	9,868.50	204,000	1,558	1,059	1917	3,870.00	80,000	624	513
1907	6,772.50	140,000	1,069	706	1918	3,628.12	75,000	573	573
1908	6,772.50	140,000	1,069	567	1919	1,983.37	41,000	313	350
1909	10,884.37	225,000	1,719	894	1920	1,935.00	40,000	348	380
1910	9,675.00	200,000	1,528	825	1921	2,418.75	50,000	448	448
1911	9,675.00	200,000	1,528	810	1922	2,418.75	50,000	423	423
1912	10,303.87	213,000	1,627	1,000					
1913	4,837.50	100,000	764	461		313,034.60	6,471,000	49,590	35,133

CHISANA DISTRICT.

In 1922 mining was carried on in the Chisana district about as usual, though operations were somewhat curtailed as the result of an unusually dry summer. Nine mines, employing 25 men, were operated in the summer and moved 10,600 cubic yards of ground that yielded an average of \$2.73 to the cubic yard. Practically all mining in this camp is now done by the use of automatic dams, with the aid of which the overburden is washed away, the bedrock being cleaned by pick and shovel methods.

Placer gold and silver produced in the Chisana district, 1913–1922.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1913	1,935.00	\$40,000	465	\$280	1919	1,306.12	\$27,000	314	\$352
1914	12,093.75	250,000	2,910	1,609	1920	967.50	20,000	137	150
1915	7,740.00	160,000	1,862	944	1921	1,112.62	23,000	164	164
1916	1,935.00	40,000	465	306	1922	1,402.87	29,000	200	200
1917	1,935.00	40,000	420	346					
1918	725.63	15,000	160	160		31,153.49	644,000	7,097	4,511

BONNIFIELD DISTRICT.

The Bonnifield placer district extends from Nenana River eastward to and including the Wood River basin and is in general coextensive with the Nenana coal field. Placer mining has been carried on in this district for 20 years, and the production, though small, has been steady. In 1922 two hydraulic plants were installed, one on Totatlanika River near the mouth of Iron Creek and the other on Platte Creek. The district contains extensive gravel deposits that carry gold, and careful prospecting may reveal localities where it will pay to mine these deposits on a large scale. The coal-mining operations in the region have been described on page 20. Further development work was done on a gold-bismuth quartz prospect[11] on Eva Creek, a headward tributary of Moose Creek about 10 miles east of the railroad. No ore was shipped, but assay returns are reported to show a large body of ore carrying a promising content of gold. In 1922 seven placer mines, employing 24 men, were operated and handled 3,500 cubic yards of gravel carrying \$2.86 in gold to the cubic yard.

[11] Overbeck, R. M., Lode deposits near the Nenana coal field: U. S. Geol. Survey Bull. 662, pp. 351-362 1918.

Placer gold and silver produced in the Bonnifield district, 1903–1922.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1903–1906..	1,451.25	$30,000	227	$136	1916.......	483.75	$10,000	76	$50
1907.......	241.87	5,000	38	25	1917.......	580.50	12,000	98	81
1908.......	241.87	5,000	38	20	1918.......	580.50	12,000	91	91
1909.......	2,418.75	50,000	379	197	1919.......	483.75	10,000	75	84
1910.......	483.75	10,000	76	41	1920.......	241.87	5,000	38	41
1911.......	967.50	20,000	152	81	1921.......	774.00	16,000	114	114
1912.......	967.50	20,000	152	93	1922.......	483.75	10,000	73	73
1913.......	967.50	20,000	152	92					
1914.......	1,451.25	30,000	227	126		13,786.86	285,000	2,158	1,422
1915.......	967.50	20,000	152	77					

KANTISHNA DISTRICT.

The following notes on mining in the Kantishna district in 1922 are based on observations by Philip S. Smith, of the Geological Survey, who visited the district in July, 1922.

Gold placers.—Gold placer mining was continued in a small way, mainly by pick and shovel methods, on the streams that have been worked for many years. The principal operations of this type were on Eureka Creek, where four men were employed; in the Glen Creek basin, where five men were mining; in the Spruce Creek basin, where four men did a little mining; and on Glacier Creek, where there were a few small operations. Little was accomplished on Little Moose Creek in 1922. The outstanding developments in the district were the initial mining operations of two large hydraulic plants, one on Moose Creek and one on Caribou Creek.

The Kantishna Hydraulic Mining Co. was mining gravels in the valley of Moose Creek near the mouth of Eldorado Creek. This company owns claims extending for about 3 miles downstream below Eldorado Creek. Water for mining is brought by a ditch from the stream draining from Wonder Lake, but in 1922 considerable difficulty was experienced in keeping the ditch in repair, and breaks, with consequent interruption to mining, were frequent. Sufficient water was available to operate two giants most of the season, and three were operated part of the time. The ground mined is relatively shallow and full of large boulders, and the gold occurs on a false bedrock of sticky blue clay. Many of the boulders are too large to be rolled aside and must be broken by explosives before they can be moved. This delays operations and adds considerably to the cost of mining. The gold is somewhat rusty red, moderately angular, and not very coarse. The largest pieces do not exceed a few dollars in value, and pieces worth 5 cents are larger than the average. A large amount of gravel was sluiced at this plant during the season, but the recovery is said to have been less than prospecting had indicated.

The Mount McKinley Gold Placers (Inc.), after several years of preparatory work, began mining in 1922 on a large holding of placer ground on Caribou Creek, some 40 men being employed. Water was obtained from Caribou Creek for hydraulic operations, but construction was under way on a higher ditch, to take water from the same stream near the mouth of Last Chance Creek. In 1922 there was an unusually heavy rainfall, as a consequence of which mining was at times hampered by the high water and dams were washed out. Supplies were brought to this property from the head of launch navigation on Bearpaw River, at Diamond, by caterpillar tractor, but the bad trail made its operation slow and expensive. It is reported that this trail is now being improved. At the workings the gold was recovered from a false bedrock of yellowish muddy clay, though true bedrock is found at other places on Caribou Creek. The gravel mined contained many large boulders that greatly increased the cost of mining. The gold, which is rough and rather fine, occurs in association with black sand and considerable garnet. It is said that the large cut mined in 1922 gave a disappointingly low yield of gold.

Placer gold and silver produced in the Kantishna district, 1903–1922.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1903–1906	8,465.62	$175,000	1,325	$795	1916	1,451.25	$30,000	227	$149
1907	725.62	15,000	114	75	1917	725.63	15,000	120	99
1908	725.62	15,000	114	60	1918	1,451.25	30,000	227	227
1909	241.87	5,000	38	20	1919	725.63	15,000	114	128
1910	483.75	10,000	76	41	1920	1,209.37	25,000	320	349
1911	1,451 25	30,000	227	120	1921	580.50	12,000	156	156
1912	1,451.25	30,000	227	140	1922	1,548.00	32,000	403	403
1913	1,451.25	30,000	227	137					
1914	967.50	20,000	152	84		24,622.86	509,000	4,219	3,060
1915	967.50	20,000	152	77					

Gold and silver lode mining.—No productive lode mining was done in the Kantishna district in 1922. Underground and surface prospecting was continued on the Quigley claims, on lower Friday Creek, and some very promising ore was disclosed. No noteworthy work was done on the claims at the head of Friday Creek or on the divide between Friday and Eureka creeks. Several new lodes, the importance of which has not been determined, are reported on Glen and Eldorado creeks.

In the vicinity of Copper Mountain, near Muldrow Glacier, a large number of claims were staked in 1921 and 1922, but development work has so far been confined to a few shallow pits and open cuts. Considerable difficulty was encountered in starting underground prospecting tunnels on these claims, for in those places where the most promis-

ing mineralized rock was found the rock was badly broken, and as soon as an excavation was made the loose material on the hillside would begin to slide. This naturally interfered with the prospecting of the richer areas. The mineralization in the Copper Mountain district was extensive, and the geology is very complex. The ore occurs mainly as stringers in limestone near the contact of acidic or basic intrusive rocks, in quartzite beds, or in the igneous rocks themselves. There seem to have been two distinct types of mineralization—a copper mineralization that apparently was related to the basic intrusive rocks and a lead-zinc mineralization that was related to the granitic rocks. There are numerous faults and slips, both older and younger than the mineralization. The older ones were followed, to some extent, by the mineralizing solutions and the younger ones cut off and displaced the ore bodies. Further prospecting will be necessary to determine the size and value of these ore deposits.

RUBY DISTRICT.

There was a considerable falling off in the gold production of the Ruby district in 1922, although more mines were in operation and more miners were employed than in 1921. The decline was due in part to the exhaustion of some of the richer ground, the average gold recovery in 1922 being $3.50 to the cubic yard, as compared with $4.50 per yard in 1921. In 1922 there were operated 24 summer mines, employing 67 men, and 13 winter mines, employing 39 men The largest production was reported from Poorman, Solomon, Flat, Spruce, and Trail creeks. The Perseverance lead-silver lode mine produced 50 tons of very high grade ore.

Placer gold and silver produced in the Ruby district, 1907–1922.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1907–8	48.38	$1,000	7	$4	1918	19,350.00	$400,000	3,000	$3,000
1912	8,465.63	175,000	1,157	712	1919	7,981.88	165,000	1,255	1,406
1913	37,974.37	785,000	5,188	3,134	1920	8,223.75	170,000	1,113	1,213
1914	48,375.00	1,000,000	6,609	3,655	1921	8,223.75	170,000	1,158	1,158
1915	33,862.50	700,000	4,626	2,345	1922	5,950.13	123,000	819	819
1916	41,118.75	850,000	5,618	3,697					
1917	42,811.88	885,000	6,073	5,046		262,386.02	5,424,000	36,643	26,189

INNOKO AND TOLSTOI DISTRICTS.

In the Innoko district 18 summer mines, employing 62 men, and 4 winter mines, employing 6 men, were operated in 1922. The chief production came from Little, Ophir, Yankee, Gaines, and Anvil creeks. Open-cut mining predominates, but with the continuous installation of dredges it is to be expected that this type of mining

will eventually surpass in production the open-cut methods. The Flume Dredge Co.'s dredge on Yankee Creek, first put into operation in 1921, mined continuously during the summer of 1922, and its success was sufficient to encourage the same company to start the installation of a similar dredge on Little Creek, which should be in operation in 1923. A 6-mile ditch was under construction along Innoko River to provide water for a hydroelectric plant to supply power for these dredges. The Innoko Dredging Co. landed the materials for a steam dredge at Tacotna in the fall of 1922 and sledded it to Gaines Creek during the winter. It was hoped to put this dredge to digging in 1923. In 1922 a total of 222,500 cubic yards of gravel was mined, carrying an average gold content of $1 to the yard.

In the Tolstoi district 4 mines were operated in summer and 4 in winter. Each mine was a one-man property, operated by the owner alone. Work was confined to Madison, Esperanto, and Bear creeks, but it was expected that Boob Creek would be opened up in 1923.

Placer gold and silver produced in the Innoko and Tolstoi districts, 1907–1922.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1907	628.87	$13,000	67	$44	1916	10,642.50	$220,000	1,130	$744
1908	3,483.00	72,000	370	196	1917	8,465.63	175,000	1,113	917
1909	16,447.50	340,000	1,746	908	1918	5,805.00	120,000	608	608
1910	15,721.87	325,000	1,669	901	1919	6,772.50	140,000	717	803
1911	12,093.75	250,000	1,284	681	1920	4,982.62	103,000	529	577
1912	12,093.75	250,000	1,284	681	1921	5,321.25	110,000	569	569
1913	13,545.00	280,000	1,438	869	1922	10,836.00	224,000	1,264	1,264
1914	9,675.00	200,000	1,027	568					
1915	9,191.25	190,000	976	495		145,705.49	3,012,000	15,791	10,825

IDITAROD DISTRICT.

There were 13 productive mines, employing 136 men, in the Iditarod district in 1922. The two dredges on Otter Creek worked 163 and 167 days and produced a large part of the total gold output of the district. Otter, Happy, Flat, and Willow creeks were the chief producers The average gold recovery for the entire district was about 51 cents a yard, and 547,300 yards of gravel was moved. The large yardage and small average recovery are of course the result of dredge mining.

A promising discovery of gold quartz is reported to have been made by J. Warren at the head of Glen Gulch. It is said that a stamp mill has been installed and considerable ore mined. Plans were made to send a sample shipment to Tacoma to be smelted, but the high freight charges make it impossible to ship any but bonanza ore from this district. The quicksilver mine in the headwater region of Iditarod River was not operated in 1922.

Placer gold and silver produced in the Iditarod district, 1910–1922.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1910	24,187.50	$500,000	4,254	$2,297	1918	59,985.00	$1,240,000	9,000	$9,000
1911	120,937.50	2,500,000	21,270	11,273	1919	35,071.88	725,000	5,300	5,937
1912	169,312.50	3,500,000	29,778	18,313	1920	24,429.37	505,000	3,628	3,954
1913	89,977.50	1,860,000	9,551	5,769	1921	16,931.25	350,000	2,482	2,482
1914	99,652.50	2,060,000	10,578	5,849	1922	13,545.00	280,000	2,041	2,041
1915	99,168.75	2,050,000	10,526	5,337					
1916	94,331.25	1,950,000	10,013	6,589		920,092.50	19,020,000	129,471	87,946
1917	72,562.50	1,500,000	11,050	9,105					

MARSHALL DISTRICT.

About 12 summer mines, employing 31 men, were operated in the Marshall district of the lower Yukon during 1922. This district is here made to include the Stuyahok region, about 40 miles northeast of Marshall. There was very little activity around Marshall in 1922, and reports from the Stuyahok were not very encouraging. Four men mined on Disappointment Creek, near the original Marshall discovery, operating a hydraulic plant and a scraper. One new encouraging prospect was said to have been found on claim No. 2. In this district about 17,000 cubic yards of ground was mined, from which an average of $1.29 in gold was recovered.

Placer gold and silver produced in the Marshall district, 1914–1922.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1914	725.62	$15,000	94	$52	1920	4,353.75	$90,000	552	$602
1915	1,209.37	25,000	156	79	1921	1,451.25	30,000	192	192
1916	13,061.25	270,000	1,686	1,109	1922	1,064.25	22,000	134	134
1917	20,559.37	425,000	3,300	2,719					
1918	7,256.25	150,000	940	940		54,518.61	1,127,000	7,678	6,526
1919	4,837.50	100,000	624	699					

CHANDALAR DISTRICT.

According to reports received, 4 summer mines, employing 15 men, and 1 winter mine, employing 10 men, were operated in the Chandalar district in 1922. The greater part of the production from the district came from a single deep mine on Little Squaw Creek, operated by F. J. Smith, which was worked only in the winter. Plans were made to run a drainage tunnel to this ground, so that mining could be carried on in the summer of 1923. Big Creek was the second largest producer in the district. In the entire Chandalar district about 22,000 yards of ground was mined in 1922, having an average gold content of $3.73 to the cubic yard.

Prospecting continues on the gold lodes of this district. For many years promising gold quartz lodes have been held, but the remoteness of the region and the high cost of bringing mining machinery to it have retarded lode-mining developments. There are indications that eventually the Chandalar region will be included in the list of gold-lode camps.

Placer gold and silver produced in the Chandalar district, 1906–1922.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1906–1912..	2,902.50	$60,000	416	$241	1919.......	483.75	$10,000	79	$88
1913.......	266.06	5,500	38	23	1920.......	870.75	18,000	125	136
1914.......	241.87	5,000	35	19	1921.......	1,451.25	30,000	197	197
1915.......	241.87	5,000	35	18	1922.......	4,015.12	83,000	574	574
1916.......	435.37	9,000	62	41					
1917.......	725.63	15,000	104	86		12,263.05	253,500	1,761	1,519
1918.......	628.88	13,000	96	96					

KOYUKUK DISTRICT.

In the Koyukuk district 36 summer placer mines, employing 106 men, and 10 winter mines, employing 25 men, were productively operated in 1922. An average of $3.44 in gold to the cubic yard was recovered from the 38,350 cubic yards of gravel mined. As in the past, the largest output came from Nolan Creek. A new piece of rich bench ground was opened up on Nolan Creek below the mouth of Smith Creek, but its extent is still unknown. Some recently discovered rich spots on Hammond River have stimulated prospecting there, and some coarse gold was mined on Sixtymile River, a tributary of John River.

Placer gold and silver produced in the Koyukuk district, 1900–1922.[a]

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1900–1909..	106,454.02	$2,200,600	15,242	$8,993	1917.......	12,287.26	$254,000	1,724	$1,421
1910.......	7,740.00	160,000	1,108	598	1918.......	7,401.38	153,000	880	880
1911.......	7,256.25	150,000	1,039	551	1919.......	5,514.75	114,000	787	881
1912.......	10,860.19	224,500	1,555	957	1920.......	4,402.12	91,000	148	161
1913.......	20,898.00	432,000	2,991	1,806	1921.......	3,773.25	78,000	119	119
1914.......	13,786.87	285,000	1,973	1,091	1922.......	6,385.50	132,000	214	214
1915.......	14,028.75	290,000	2,006	1,017					
1916.......	15,480.00	320,000	2,216	1,458		236,268.34	4,884,100	32,002	20,147

[a] Beginning with 1911 this table includes a small production from the Indian River district.

KUSKOKWIM REGION.

The returns from the placer operations in the Kuskokwim region are still incomplete, so a full statement of mining in 1922 is not possible. About 30 mines, employing about 137 men, were operated and produced about $542,000. Much the largest single operation was that of the dredge on Candle Creek near McGrath. This dredge operated during a period of 145½ days, digging in ground that averaged 14½ feet in depth. In addition to the dredging, about 7 mines were operated in the McKinley district, 7 in the Georgetown district, 11 in the Tuluksak-Aniak district, and 4 in the vicinity of Goodnews Bay.

Mining and development work was continued on the Nixon mines of the Treadwell Yukon Co. (Ltd.), at Nixon Fork, in the McKinley district. The company reports that 200 feet of inclined shaft and 1,690 feet of drifts and crosscuts were completed. The 10-stamp amalgamating and concentrating mill, erected in 1921, was operated from June to September, 1922, and the mine was operated continuously throughout the year. Some development work was done on the quicksilver deposits of the lower Kuskokwim and on one or two other lode deposits.

SEWARD PENINSULA.

SALIENT FEATURES.

The value of the total mineral production of Seward Peninsula in 1922 was $1,274,988, a falling off of $190,000 from the value in 1921. Of the total amount $1,265,000, as shown in the subjoined table, was in gold, and the rest in silver, platinum, coal, and lead. No tin was produced in Seward Peninsula in 1922. The platinum came chiefly from the Koyuk district and the lignitic coal from the Fairhaven district. At the Independence mine, in the Fairhaven district, no new ore was mined, but a small production was made by working over the dumps of the preceding year. This was the only producing lode mine on the peninsula in 1922. Some development work, mainly as assessment work, was done on other lodes of the district.

PLACER MINING.

A total of 104 placer mines, employing about 528 men, were operating on Seward Peninsula in the summer of 1922, and 11 mines, employing 51 men, the preceding winter. In 1921 there were about 126 summer mines, employing 622 men, and 14 winter mines, employing 64 men. These mines in 1922 moved an aggregate of about 2,103,691 yards of ground, which yielded about 60 cents in gold to the cubic yard.

Two interesting new discoveries of placer gold, the value of which has not yet been determined, are reported from the Buckland River basin, about 25 miles above the mouth of that stream.

Placer gold produced in Seward Peninsula in 1922, by districts.

District.	Value of gold.	Summer.		Winter.	
		Mines.	Miners.	Mines.	Miners.
Nome	$485,000	26	164	3	16
Solomon and Casadepaga	111,000	14	61		
Koyuk	109,000	11	78	4	25
Council	375,000	11	89	1	3
Kougarok	32,000	11	35		
Fairhaven	150,000	26	93	3	7
Port Clarence	3,000	5	8		
	1,265,000	104	528	11	51

Placer gold produced in Seward Peninsula in 1922, by methods of mining.

Method.	Mines.	Men.	Value of gold.
Dredging	15	151	$609,859
Hydraulic mining (includes all operations where any water is used to move gravel to sluice box)	24	192	426,671
Open-cut mining (other than by hydraulicking)	59	136	117,736
Drifting	17	100	110,734

The 15 dredges operated on Seward Peninsula in 1921 dug about 1,574,500 cubic yards, as compared with 16 gold dredges and about 1,690,000 cubic yards in 1921. The gold recovery to the cubic yard was about 39 cents in 1922 and 41 cents in 1921. The dredges were operated from 13 to 114 days. Those that were fully prepared at the beginning of the operating season worked from 70 to 114 days. The most important event of mining interest in the Seward Peninsula region in 1922 was the acquiring of large dredging-ground holdings, including all the property of the old Pioneer Mining Co., by the Hammon Consolidated Goldfields Co. The property of the Pioneer Mining Co. has been worked mainly by hydraulic giants and elevators. The new company has let contracts for two new dredges, with buckets having a capacity of 9 cubic feet, to be erected and ready for operation on ground on the third beach by June, 1923. The cold-water thawing method will be used to keep the ground thawed in advance of dredging. The dredges will be electrically operated, the power being furnished by Diesel engines.

The hydraulic mines of Seward Peninsula handled about 468,327 cubic yards of gravel and made an average gold recovery of 91.1 cents. About 21,118 cubic yards was mined by drifting and hoisting, with a gold recovery of about $5.24 to the cubic yard. Most of the deep mining was done in the Koyuk district. Open-cut mines other than

hydraulic mined 39,792 cubic yards of ground and recovered $3 to the yard in gold.

Gold and silver produced on Seward Peninsula, 1897–1922.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.		Fine ounces.	Value.	Fine ounces.	Value.
1897......	725.63	$15,000	87	$52	1911......	149,962.50	$3,100,000	17,996	$9,718
1898......	3,628.12	75,000	435	256	1912......	145,125.00	3,000,000	17,415	10,710
1899......	135,450.00	2,800,000	16,254	9,752	1913......	120,937.50	2,500,000	12,094	7,305
1900......	229,781.25	4,750,000	27,574	17,097	1914......	130,612.50	2,700,000	15,673	8,667
1901......	199,822.61	4,130,700	24,579	14,747	1915......	140,287.50	2,900,000	17,510	8,878
1902......	220,677.07	4,561,800	26,481	14,035	1916......	142,706.25	2,950,000	14,271	9,391
1903......	215,994.38	4,465,000	24,171	13,052	1917......	125,775.00	2,600,000	13,770	11,346
1904......	201,462.52	4,164,600	24,175	14,021	1918......	53,599.50	1,108,000	6,022	6,022
1905......	232,200.00	4,800,000	27,864	16,997	1919......	65,790.00	1,360,000	6,940	7,773
1906......	352,812.50	7,500,000	43,537	29,605	1920......	62,887.49	1,300,000	6,813	7,426
1907......	338,625.00	7,000,000	25,497	16,828	1921......	70,389.75	1,455,085	6,411	6,411
1908......	247,680.00	5,120,000	20,577	10,905	1922......	61,194.37	1,265,000	6,790	6,790
1909......	207,077.50	4,260,000	20,871	10,853					
1910......	169,312.50	3,500,000	20,317	10,971		4,024,516.44	83,380,185	444,124	279,608

KOBUK REGION.

Placer mining continued during 1921 in a small way in the Kobuk River basin, chiefly in the Shungnak district. About 6 summer mines, employing 11 men, and 3 winter mines, employing 8 men, were operated, most of them for only a part of the season. Klery and Dahl creeks were the largest producers, but the total output was only about $8,000 in gold. It is reported that two hydraulic plants are being installed in this region, one of them on California Creek.

ADMINISTRATIVE REPORT.

By Alfred H. Brooks and George C. Martin.

During 1922 seven parties were engaged in surveys and investigations in Alaska. These parties included 7 geologists, 2 topographers, 2 topographic assistants, and 12 packers, cooks, and other helpers. Five parties were engaged in geologic work, and two were combined geologic and topographic parties.

The funds available for field and office work for the season of 1922 included an appropriation of $75,000, an unexpended balance of $5,430 from the appropriation of 1921, and an allotment of $2,000 from the appropriation of 1921 for the classification of the public lands. The subjoined tables show the allotments of these funds geographically by types of work and by salaries and field expenses. A balance of $14,100 will be used for the field work of 1923. In these tables the money devoted purely to office work has not been allocated to the several projects, except as indicated.

Allotments for salaries and field expenses, field season of 1922.

	1921–22	1922–23
Scientists' salaries	....	$28,400
Field expenses	$7,430	17,000
Miscellaneous expenses, including clerical salaries, etc.	....	9,500
Office of Director	....	6,000
To be allotted to field work, 1923	....	14,100
	7,430	75,000

The allotments shown in the subjoined tables as made to different kinds of work and to different regions are only approximations. To determine the precise figures would require an elaborate cost-keeping system too expensive to justify the results to be achieved. Many parties and individuals divide their time between two or more projects. The following table shows, in a general way, however, on what projects the funds have been spent. The geologic surveys include work that is used in the classification of public lands.

Approximate allotments to different kinds of surveys and investigations, field season of 1922.

	1921–22	1922–23
Special investigations of geology and mineral resources	....	$10,700
Reconnaissance geologic surveys	$3,130	20,500
Reconnaissance topographic surveys	4,300	9,700
Map compilation	....	4,100
Collecting mineral statistics	....	2,400
Administration, Alaska branch, including clerical salaries, miscellaneous expenses, etc	....	7,500
Office of Director	....	6,000
To be allotted to field work, 1923	....	14,100
	7,430	75,000

In the following table showing the distribution of allotment by regions, the overhead expenses, including administration, are distributed proportionately among the various projects:

Approximate distribution of allotments for investigations in Alaska, field season of 1922.

	1921–22	1922–23
General investigations, geology and mineral resources	....	$9,600
Southeastern Alaska	....	5,400
Copper River	....	8,400
Alaska Railroad	....	4,200
Alaska Peninsula	$6,450	18,400
Yukon basin	980	6,600
Map compilation	....	5,200
Collecting mineral statistics	....	3,100
To be allotted to field work, 1923	....	14,100
	7,430	75,000

The following table shows the progress of investigations in Alaska and the annual grants of funds since systematic surveys were begun, in 1898.[1] It should be noted that a varying amount is spent each year on special investigations that yield results which can not be expressed in terms of area. In 1917, when the United States entered the World War, nearly all the Alaska funds were allotted to the investigation of minerals such as platinum, sulphur, and antimony, which were then of special importance, and few areal surveys were made. Since 1918 the reduction of the annual appropriation and the increased cost of all field work has not permitted extensive geologic and topographic surveys. Little progress has therefore been made in extending the topographic and geologic mapping that is essential to obtain an adequate knowledge of the mineral resources of the Territory.

[1] The Geological Survey made some investigations of the gold and coal deposits of the Pacific seaboard region in 1895 and of the Yukon region in 1896.

Progress of surveys in Alaska, 1898–1922.

Year.	Appropriation.	Areas covered by geologic surveys.			Areas covered by topographic surveys.[a]					Investigations of water resources.	
		Exploratory (scale 1:625,000 or 1:1,000,000).	Reconnaissance (scale 1:250,000).	Detailed (scale 1:62,500).	Exploratory (scale 1:625,000 or 1:1,000,000).	Reconnaissance (scale 1:250,000; 200-foot contours).	Detailed (scale 1:62,500; 25, 50, or 100 foot contours).	Line of levels.	Bench marks set.	Gaging stations maintained part of year.	Stream-volume measurements.
		Sq. m.	*Sq. m.*	*Sq. m.*	*Sq. m.*	*Sq. m.*	*Sq. m.*	*Miles.*			
1898	$46,189	9,500			12,840	2,070					
1899	25,000	6,000			8,690						
1900	60,000	3,300	6,700		630	11,150					
1901	60,000	6,200	5,800		10,200	5,450					
1902	60,000	6,950	10,050		8,330	11,970	96				
1903	60,000	5,000	8,000	96		15,000					
1904	60,000	4,050	3,500		800	6,480	480	86	19		
1905	80,000	4,000	4,100	536		4,880	787	202	28		
1906	80,000	5,000	4,000	421		13,500	40			14	286
1907	80,000	2,600	1,400	442		6,120	501	95	16	48	457
1908	80,000	2,000	2,850	604		3,980	427	76	9	53	556
1909	90,000	6,100	5,500	450	6,190	5,170	444			81	703
1910	90,000		8,635	321		13,815	36			69	429
1911	100,000	8,000	10,550	496		14,460	246			68	309
1912	90,000		2,000	525			298			69	381
1913	100,000	3,500	2,950	180	3,400	2,535	287				
1914	100,000	1,000	7,700	325	600	10,300	10				
1915	100,000		10,700	200		10,400	12	3	2	9	
1916	100,000		5,100	636		9,700	67			20	
1917	100,000		1,750	275		1,050				19	
1918	77,000		3,500			1,200					
1919	75,000		2,700			2,300				19	
1920	75,000		1,480			770				19	
1921	[b] 87,000		2,130	150		300	205				
1922	[c] 77,000		4,000			4,300					
	1,952,189	73,200	115,095	5,657	51,680	156,900	3,936	462	74		
Percentage of total area of Alaska		12.48	19.63	0.96	8.81	26.76	0.67				

[a] The Coast and Geodetic Survey, International Boundary Commission, and General Land Office have also made topographic surveys in Alaska. The areas covered by these surveys are of course not included in these totals.

[b] Includes $12,000 for classification of public lands.

[c] Includes $2,000 for classification of public lands.

The chief Alaskan geologist was engaged in office work until June 12, 1922, when he left Washington for Seattle, where he joined Hon. C. H. Huston, Assistant Secretary of Commerce, and other members of an expedition sailing on the Coast Guard cutter *Mojave* to make investigations in the northern Pacific under the auspices of the Department of Commerce. With this party he visited and made some investigations of the geology and mineral resources in the coastal regions of Alaska and adjacent islands, as well as of the geology and geography of portions of the coast of Siberia. While in Alaska he visited Juneau, Seward, Anchorage, Fairbanks, Unalaska and Pribilof Islands, and Nome. His time in the office was divided as follows: Geologic studies, 14½ days; progress report, 15 days; press bulletin, 10 days; mineral statistics, 17 days; geology of Alaska, 24 days; geography and geology of eastern Siberia, 29 days; field plans and

orders, 14½ days; preparation of report on geology of Point Barrow region and plans for survey of naval petroleum reserve No. 4, 32 days; administrative and routine matters, the remainder. He left Washington June 21, 1923, to make certain inquiries in Seattle, and on June 29 sailed for Sydney, Australia, where he attended the Pan Pacific Conference as an official delegate.

George C. Martin did no field work in the summer of 1922 and was engaged throughout the year in geologic studies of the Alaska Mesozoic formations and in administrative duties as acting chief Alaskan geologist during the absence of Mr. Brooks. His time was divided as follows: Preparation of manuscript on Alaska Mesozoic formations, 121 days; revision of reports and preparation of original manuscript on Alaska oil fields, 32 days; revision of other referred manuscript and proof reading, 28 days; general administrative duties, including conferences, 49 days; preparation of manuscript of administrative reports, 6 days; preparation of manuscript and other data for Government officials outside of the Geological Survey, 14 days. The entire month of June, 1923, was spent in official travel on the way to the oil fields of Alaska Peninsula.

Philip S. Smith spent from June 14 to September 13 in making special investigations of the geology and mineral resources of areas adjacent to the Alaska Railroad.

Fred H. Moffit was engaged from June 14 to September 17 in a revision and extension of the reconnaissance geologic mapping of the Chitina Valley. The results of his investigations will appear in a summary report on the geology and mineral resources of the Chitina quadrangle.

J. B. Mertie, jr., continued the reconnaissance geologic mapping of parts of the Rampart and Fairbanks quadrangles. He spent from June 27 to September 3 in mapping, on the scale of 1 to 100,000, an area of about 1,000 square miles. Some time in September was spent in collecting statistics of mineral production in the vicinity of Fairbanks.

A. F. Buddington spent from June 13 to September 22 in continuing the geologic mapping and investigation of mineral resources of the Wrangell district.

R. H. Sargent was in charge of a double party engaged in reconnaissance topographic and geologic surveys of the oil fields of the Alaska Peninsula. Mr. Sargent spent from June 15 to September 22 in mapping on the scale of 1 to 180,000 an area of about 3,000 square miles lying along the axis of the Alaska Peninsula between Portage Bay and Chignik. He was accompanied by W. R. Smith, who made geologic surveys in the same district, and had general supervision of a party under the leadership of R. K. Lynt engaged in making surveys in an adjacent area. While in the office Mr. Sargent was

occupied largely in the administration of Alaska topographic surveys and map compilation, in addition to preparing his field maps for publication.

W. R. Smith, who accompanied R. H. Sargent from Portage Bay to Chignik, made reconnaissance geologic surveys of an area of about 2,000 square miles. A joint report on the results of his investigations and on those of Mr. Baker in an adjoining area appears elsewhere in this volume.

R. K. Lynt spent from June 15 to September 12 in making topographic surveys on the scale of 1 to 180,000 of an area of about 1,300 square miles in the vicinity of Becharof Lake. He was accompanied by A. A. Baker, who made geologic surveys of an area of 475 square miles in the same district. The results of Mr. Baker's investigations are published, jointly with those of W. R. Smith, elsewhere in this volume.

S. R. Capps, who had been on furlough since April 16, 1922, while engaged in commercial oil work for an American company in foreign countries, returned to the Geological Survey May 1, 1923, and resumed the preparation of his report on the geology and mineral resources of the region tributary to the Alaska Railroad. In June, 1923, in the absence of Mr. Brooks and Mr. Martin, he took over administrative charge of the Alaska branch as acting chief Alaskan geologist.

C. Arthur Hollick continued his studies of the Alaska Tertiary fossil plants, although he was not regularly employed by the survey.

James McCormick was employed for six months in the revision of the geographic dictionary of Alaska. John B. Torbert has been engaged in Alaska cartographic work throughout the year, about half of his time having been devoted to map compilation. E. B. Hill, assistant topographic engineer, was engaged in work upon Alaska topographic maps from November 15 to January 23.

Miss Lucy M. Graves, chief clerk, has continued to carry much of the clerical administration of the Alaska branch and has acted as chief during the absence of the chief Alaskan geologist and of the senior geologist, G. C. Martin. The details of collecting the statistics of the mineral production of Alaska have been in the hands of T. R. Burch.

During 1922 the survey issued three complete bulletins relating to Alaska—Bulletin 722, "Mineral resources of Alaska, 1920," by Alfred H. Brooks and others; Bulletin 733, "The geology of the York tin deposits, Alaska," by Edward Steidtmann and S. H. Cathcart; and Bulletin 742, "Chromite of Kenai Peninsula, Alaska," by A. C. Gill; also some of the separate chapters from Bulletin 739, "Mineral resources of Alaska, 1921," by Alfred H. Brooks and others. Bulletin 745, "The Kotsina-Kuskulana district, Alaska,"

including topographic maps, by F. H. Moffit and J. B. Mertie, jr., was issued in June, 1923. The manuscripts of three other reports—"The Ruby-Kuskokwim region, Alaska," by J. B. Mertie, jr., and G. L. Harrington (Bulletin 754), "The Juneau district, Alaska," by H. M. Eakin, and "The Ketchikan district," by Theodore Chapin are nearly ready for the printer. The usual annual review of the mining industry of Alaska was issued on December 31, 1922.

A new map of Alaska on the scale of 1 to 2,500,000 was issued about March 1, 1923. A relief map on the same scale is almost completed. The compilation of the topographic map of the region tributary to the Alaska Railroad, on a scale of 1 to 250,000, is approaching completion. This will be published in three sheets, of which the southern sheet (Seward-Matanuska) was sent to the engraver in June, 1923.

THE METALLIFEROUS DEPOSITS OF CHITINA VALLEY.

By Fred H. Moffit.

INTRODUCTION.

The mineral deposits of the Copper River basin, particularly of Chitina Valley, have been described from time to time during a period of many years in papers of the United States Geological Survey and in the scientific and technical journals. These papers are widely scattered in many publications, some of them long out of print, so that much of the information they contain is no longer generally available. The writer expects to collect into a single paper the general facts of the geology and mineral resources of this region, but meantime it appears desirable, especially for the benefit of those who wish to search for new mineral deposits or to test the value of known deposits, to summarize briefly the mode of occurrence of the valuable minerals so far discovered and to point out their relation to the geologic formations and structure. This paper is intended to present such a summary. It deals primarily with Chitina Valley but contains some references to adjoining districts. Attention is given mostly to minerals and mineral deposits that are already of economic importance.

Copper, gold, and silver are the only commercially valuable minerals that have yet been produced in the district under consideration. They are named in the order of the money value of the metal already mined, and the value of the copper far exceeds that of the gold and silver. Both copper and gold are mined for themselves alone, but silver is produced almost wholly in connection with the mining of copper, although a much smaller quantity is obtained from the gold placers and a single silver-gold vein. Gold is produced chiefly from placer gravels, where it is commonly found with considerable native copper and a small amount of silver. It is also obtained from the gold-silver vein mentioned.

GENERAL GEOLOGY.

The rocks of Chitina Valley are prevailingly sedimentary rocks, such as limestone, shale, conglomerate, sandstone, and chert, but include also intrusive rocks and a great succession of lava flows.

The oldest known rocks of the district are included in the Strelna formation, probably of Mississippian age, which occupies much of the main valley of Chitina River. They comprise shale or slate, limestone, chert, tuff, and basic lava flows intruded by granular igneous rocks, including granodiorite, diorite, and gabbro. Both copper and gold are found in some of the rocks of this formation.

Overlying the Strelna formation is the Nikolai greenstone, a widespread succession of basic lava flows with a total thickness of not less than 4,000 feet. The structural relation of the Nikolai greenstone to the Strelna formation has not been understood but from observations made in 1922 appears to be that of unconformity, possibly without discordance in dip—that is, the Strelna formation may have undergone erosion without deformation before the Nikolai basalt flows were poured out. The precise age of the Nikolai greenstone, furthermore, is not definitely known but is indicated within limits by the fact that the greenstone overlies Permian sandstone and conglomerate in the valley of Chitistone River and underlies Upper Triassic limestone in many places. Copper in small amounts is found almost everywhere in the Nikolai greenstone, a fact that may be of great significance in connection with the origin of the copper deposits.

The Nikolai greenstone is overlain, without apparent unconformity, by a great thickness of Upper Triassic sediments, the lower part of which consists of limestone, long known as the Chitistone limestone, and the upper part of shale, known as the McCarthy shale. Since 1917, however, the name Nizina limestone has been applied to the upper two-fifths or thin-bedded part of the original Chitistone limestone of the Nizina district, and the name Chitistone limestone has been restricted to the lower three-fifths, consisting of more massive beds. The name Kuskulana formation has also been used to cover the Nizina limestone and the McCarthy shale of the Kotsina-Kuskulana district. The Chitistone limestone, in which the great copper ore bodies of Kennicott are found, has a thickness of about 1,800 feet, and the overlying Nizina limestone a thickness of about 1,200 feet. Their combined thickness is probably 500 feet greater than the thickness of the overlying McCarthy shale.

The Triassic and older rocks were folded, subjected to erosion for a long period, and then submerged in whole or in part below the sea, after which there were deposited on them conglomerate, sandstone, limestone, shale, volcanic tuffs, and lava flows ranging in age from Middle Jurassic to Tertiary. These later rocks, with the exception of the Cretaceous shale, which is widely developed in the Nizina district, are nowhere known to contain mineral deposits ex-

cept a few thin beds of lignitic coal and need not be considered further.

The sedimentary beds were invaded by granodioritic intrusives showing a wide range in age, texture, and color. In some places these intrusives have played an important part in the formation of metalliferous deposits.

Sometime after the formation of the youngest of the consolidated bedded rocks of the district—that is, the Tertiary sediments and volcanic beds—the region was elevated above the sea. This elevation did not take place suddenly but required a long time. It renewed the processes of erosion and gave opportunity for the streams to carve their valleys deep into the elevated sedimentary and volcanic beds, producing a rugged mountainous district with relief comparable to that of the present time. Such conditions accompanied by a less rigorous climate must have given rise to much more vigorous circulation of underground meteoric waters than is possible now or has been possible at any time since the beginning of glaciation, when the circulation of underground waters was practically stopped by ground temperatures lower than the freezing point of water. So far as the age of the metalliferous deposits, except the placer deposits, is known, they were all formed before the land took on its present form, and therefore many of them must have been subjected to chemical changes by circulating waters in preglacial time. Since glaciation began the changes in the ore deposits have been mechanical rather than chemical, consisting of such changes as would be brought about by movements in the rocks or by glacial erosion and the breaking up of deposits by frost and atmospheric weathering. Postglacial oxidation, except of a superficial kind, seems to be entirely lacking.

The topography of the district owes its present aspect in considerable measure to glaciation. With little doubt the major topographic features and most of the present drainage lines were established in preglacial time, but they have been modified by ice erosion and the deposition of ice-borne débris and the loose material carried by glacial waters. Although the glaciers are now greatly reduced, this period of glacial activity is not yet ended. It is not necessary to discuss in further detail the geologic history of the district, yet it should be borne in mind that the glacial epoch followed a much longer period of land erosion, which went on under milder climatic conditions than prevail at present, and that during this period of erosion most if not all of the metalliferous deposits were undergoing chemical changes, which were stopped by the cold and ice of the glacial epoch. This fact has an important bearing on the character of ore bodies such as those at Kennicott.

AGE OF MINERALIZATION.

A study of the ore deposits in connection with the general geology of the district leads to the conclusion that the ore bodies are to be referred to two or more periods of formation. The age of different ore bodies can not be stated definitely, but certain limitations of age can be determined. Gold, silver, or copper is found in the Strelna formation, in the Nikolai greenstone, and in the shale overlying the McCarthy shale—that is, in rocks that range in age from Mississippian (lower Carboniferous) to Upper Cretaceous. The age of the inclosing country rocks, however, tells little about the age of the mineral deposits except that the country rocks are the older. The mineral deposits may have been formed at some one particular period after the rocks were formed, or they may have been formed at different times. Moreover, the formation of the ore bodies was not a sudden process, completed at a stroke, but took place slowly as the mineral-bearing waters made their way through the devious openings in the rocks and gradually deposited their metal content.

A number of bodies of igneous rock occur in Kuskulana Valley that were intruded into Triassic and older rocks but not into sediments overlying the Triassic rocks. These intrusive bodies consist of granodiorite or closely related rocks. In places they are themselves mineralized with copper sulphides, and in places they have produced contact-metamorphic deposits of copper and other metallic minerals at the borders of the rocks which they invaded. Several large veins of magnetite were formed in this manner on MacDougall Creek. Waterworn pebbles of this magnetite have been found at the base of the Upper Jurassic (?) conglomerate that lies unconformably above the older sediments and the igneous intrusive at this place and furnish evidence that the mineralization here and probably near by on Berg Creek was later than Upper Triassic and earlier than Upper Jurassic.

Definite evidence for the age of the copper mineralization in the Nikolai greenstone and the Chitistone limestone is lacking. It may belong to either of the two periods already named or it may belong to a third distinct period. There is no reason known to the writer for supposing that the original copper mineralization took place at different times rather than as one continuous process, though doubtless the copper ores were long in the making.

It is unnecessary for the purpose of this paper to enter into a discussion of the source of the copper in the copper deposits further than to state that they were probably deposited from hot ascending solutions. A most excellent statement concerning the source of the copper and the manner of its deposition has been made by Bateman

and McLaughlin [1] as a result of a painstaking study of the ore deposits at Kennicott.

In the Nizina district the Upper Cretaceous shales are cut by many conspicuous dikes and sills of quartz diorite porphyry, and these dikes and sills are associated with veins of quartz carrying pyrite and free gold. Molybdenite is present, and probably stibnite. The creek gravels yield also galena, cinnabar, barite, and marcasite (?), but these minerals were not seen in the veins. It is evident from the age of the inclosing rocks that these minerals, or at least the veins carrying the gold, represent a period of metal deposition distinct from that previously mentioned.

CHARACTER OF THE DEPOSITS.

For convenience in description the ore deposits will be considered under the headings copper, gold, and silver, although two or more of the metals occur together at different localities and therefore the divisions overlap one another in some degree.

COPPER.

Copper is found in Chitina Valley as lodes of native copper and compounds of copper and as native copper in placer gravels. The copper minerals that have been recognized in the lode deposits include antlerite, arsenates of copper, bornite, brochantite (?), chalcanthite, chalcopyrite, chalcocite, covellite, cuprite, enargite, freibergite (?), luzonite, malachite, native copper, tennantite, and tetrahedrite. These minerals are by no means equally abundant or everywhere present. As measured by past production, chalcocite, covellite, enargite, and the carbonates azurite and malachite should be placed first, and the others, except possibly bornite, should be regarded as of little interest to the miner.

The copper lode deposits may be best considered by classifying them in accordance with the kind of rock in which they are found. Two classes are thus distinguished—copper deposits in limestone and copper deposits in lava flows, particularly in the Nikolai greenstone. These two classes differ in mineral associations and to a certain degree in form, but they are believed to belong to the same period of mineralization and to be different expressions of a single process of mineral deposition, owing their distinguishing features to the chemical and physical character of the inclosing rock rather than to differences in chemical composition of the original mineral solutions.

[1] Bateman, A. M., and McLaughlin, D. H., Geology of the ore deposits of Kennicott: Econ. Geology, vol. 15, No. 1, January, 1920.

The largest and best-known examples of copper deposits in limestone are those of Kennicott, which will therefore be described briefly as typical of this class of deposits. As given by Bateman,[2] the ore minerals at Kennicott, except those obviously due to oxidation, are chalcocite, covellite, enargite, bornite, chalcopyrite, luzonite, tennantite, pyrite, sphalerite, and galena. No gangue minerals are present. To this list should be added other minerals that are plainly due to oxidation processes. They are malachite, limonite, covellite, antlerite, azurite, arsenates of copper, chalcanthite, cuprite, and possibly brochantite. The minerals in both lists are given in the order of their abundance. It is estimated by Bateman that the sulphide ores make up approximately 75 per cent of the ores mined and that of the sulphides chalcocite constitutes from 92 to 97 per cent, covellite from 2 to 5 per cent, and other sulphides less than 1 per cent. Besides copper the ores of Kennicott carry a considerable quantity of silver, which is recovered in smelting. Very little gold is present.

The ore bodies are in the lower beds of the Chitistone limestone, which here dips 23°–30° NE. and is separated from the underlying greenstone by a bed of red and green shale ranging in thickness from 4 to 7 feet. This shale is inconspicuous but is generally present throughout the district. The ore deposits, viewed in the large, have the form of elongated tabular bodies standing on edge with their long axes approximately parallel to the dip of the limestone-greenstone contact. A cross section made by a plane parallel to the strike and perpendicular to the bedding planes of the limestone shows that the ore bodies have the form of narrow wedges with the base down and the thin edge up. The position and form of the principal ore bodies are due to two systems of faults, one of which is vertical and almost parallel to the direction of dip of the limestone, the other inclined and parallel to the limestone beds. Other faults are present but need not be considered, as they were not involved in the formation of the ore bodies. The bedding or "flat" faults are at the base of the wedge-shaped ore bodies that occupy the vertical fissures. Bateman[3] says of the ore bodies:

> The average height of the main Bonanza vein from the base to the apex, measured normal to the incline, is about 210 feet in the upper levels and 150 on the lower levels. It has been followed for a distance of about 1,900 feet, measured along its base, and the width varies from 2 to 50 feet. The main Jumbo vein, exclusive of its enlargement at the flat fault, averages about 360 feet in height, from 2 to 60 feet in width, and has been followed down on its base for 1,500 feet.

---

[2] Op. cit., pp. 35, 45.
[3] Op. cit., p. 30.

The figures for the extension of these ore bodies down the dip of the limestone are now greater than when the paper quoted was written.

The form of these ore bodies deserves special attention, because of its possible significance to the prospector. Bateman has shown by careful surveys in the Bonanza mine that the ore bodies trend parallel to the axis of a gentle transverse downfold in the Chitistone limestone, a fold whose axis pitches to the northeast, in approximately the same direction as the dip of the major folds. He suggests that the wedge-shaped form of the ore bodies results from this transverse folding, by which the beds of greater radius on the outside of the fold were under tension and tended to separate along planes of fracture, whereas the beds of shorter radius nearer the center of the fold were under compression and tended to remain closed. Folding might well result in fracturing and the formation of wedge-shaped openings whose long dimensions were parallel to the axis of the folds and whose widest parts turned downward where the folds are synclinal or upward where they are anticlinal. At the Bonanza mine the transverse folding is synclinal, and the wide parts of the ore bodies that occupy the fractured limestone turn downward, as would be required by such a method of formation. The walls of the fractures may never have been separated more than enough to allow solutions to circulate, for the folding took place slowly, and the separation may have gone on no faster than the ores were deposited. The openings may also have been enlarged by solution as the water circulated through them.

The ore bodies are not so simple in form as the preceding description may suggest. As pointed out by Bateman,[4] the ore deposits at Kennicott form vein deposits, irregularly shaped massive replacement deposits, and stockworks in the limestone. Bateman further divides the replacement deposits into irregular massive deposits, veins, and disseminated deposits, with all gradations between.

These distinctions may be better understood if the folded beds of the Chitistone limestone and the greenstone are pictured as having been subjected to forces that produced faulting with an unknown amount of movement along planes of the limestone practically parallel to the bedding and vertical fractures approximately parallel to the strike of the beds. The joint planes and openings were not everywhere simple, clean-cut, and regular. The rock in places was broken by many irregular fractures. The ore-bearing solutions made their way in the main along vertical fractures just above the bedding-plane faults but entered all other openings to which they had access. The mineral content was deposited partly in open cavities but more often

---

[4] Op. cit., p. 20.

by a replacement of the limestone itself—that is, the limestone with which the solutions came into contact was taken into solution, and copper ores were deposited in place of the dissolved limestone. In some locations the replacement of the limestone is complete so that great masses of pure copper minerals occupy the space once filled by limestone. In other localities, as in the stockworks and disseminated deposits, the replacement has not proceeded so far, and limestone forms here a small or there a large part of the ore. Irregularities of thickness of the wedge-shaped vein deposits show that the replacement went on more rapidly at some points than at others. The forms of the ore bodies are therefore dependent on the accidents of fracturing in the limestone, the facility with which the circulating waters made their way through the openings, and the degree of completeness of replacement by copper minerals.

A common experience in mining these ores is to find that an ore body terminates abruptly or that a tiny stringer of copper minerals, apparently of no value whatever, if followed a sufficient distance opens out into a large mass of ore. It is therefore necessary to explore every indication of mineralization, for otherwise valuable ore may be missed.

The original copper deposits have undergone oxidation resulting from the chemical action of surface waters, which circulated through the ore bodies at a time preceding the beginning of glaciation but practically ceased to circulate when glaciation began. No difference in the amount of oxidation has been noticed as the mine workings were carried deeper into the mountains—that is, to the 1,750-foot level. As noted before, it is estimated that 25 per cent of the ore mined is oxidized.

No other ore bodies comparable in size with those at Kennicott are known in Chitina Valley, and none similar in size and richness have been found elsewhere. Small bodies similar to those at Kennicott, however, have been found at a number of places, as near by on McCarthy Creek and on Bowlder Creek; and although they have not yet proved to be of economic value, they offer encouragement for further prospecting.

The features of the Kennicott deposits that may be of assistance to prospectors and should be kept in mind are (1) that the only productive ore bodies so far found in the district are in the Chitistone limestone; (2) that gentle transverse downfolds or synclines in the Chitistone limestone should receive special attention, because the folding may have been accompanied by the production of fractures in the limestone favorable to the circulation of ore-bearing solutions; and (3) that the most insignificant veinlets of copper

minerals in the limestone should not be neglected, for experience has shown that they may open out into large ore bodies.

It is not intended to imply that commercially valuable copper ores are unlikely to be found in the greenstone or that downfolds in the limestone are the only places favorable for ores. It can readily be seen that openings of the same nature as those described may be formed on the tops of anticlines, and that strong faults of almost any kind may furnish the opportunity for ore-bearing solutions to circulate. It is true, however, that copper deposits have not been found in the overlying Nizina limestone, which underlies the McCarthy shale.

Copper deposits in greenstone are found chiefly in the Nikolai greenstone but occur also at several localities in basaltic flows of the Strelna formation underlying the Nikolai greenstone. The latter deposits have not given much promise and for the most part resemble those in the younger flows. The copper deposits of the Nikolai greenstone are in part contact-metamorphic deposits and in part deposits produced by the action of heated circulating ground waters.

Contact-metamorphic deposits are known at two places in this region, both in Kuskulana Valley. The greenstone in the ridge between Clear and Porcupine creeks is intruded by a mass of granodiorite not readily distinguishable from the greenstone itself. Small quantities of sulphide minerals, chiefly pyrite and chalcopyrite, are nearly everywhere present in the intrusive rock, but near the contact with the greenstone the sulphides are much more abundant. The pyrite and chalcopyrite are associated with magnetite, hornblende, and pyroxene. They occur as veins and as disseminated deposits which in places form small high-grade deposits but in general are of low grade and could be mined only by handling a great quantity of country rock.

Contact-metamorphic deposits occur also on MacDougall Creek, where the geologic relations are complicated and somewhat obscure, but a large mass of light-colored quartz latite with associated porphyritic dikes was intruded into rocks that include Triassic limestone and shale and possibly some of the older rocks. Large bodies of magnetite were formed, and in places the country rock, especially the limestone, was silicified and garnetized. Veins containing pyrite and chalcopyrite cut the country rock in this vicinity and apparently represent part of the mineralization brought about by the intrusion. Some of these veins, such as that of the North Midas mine, contain gold and a considerable quantity of silver.

It is characteristic of contact-metamorphic deposits that they are irregular in form and variable in mineral content, so that the mining of such deposits often presents more uncertainties than that of vein deposits. Development work on MacDougall Creek has not met with encouraging results, and work on Clear Creek has only disclosed a large body of low-grade material that can not be mined profitably under present conditions.

The more common copper deposits in the greenstone have the form of veins, stockworks, disseminated deposits, and amygdules or fillings of the gas cavities of basaltic flows. The term " stringer lodes " has been applied to them. A brief consideration of the character and structure of the greenstone will assist in understanding the form of these copper deposits.

The Nikolai greenstone, which contains most of these deposits, includes a great thickness of basaltic lava flows covering a large area in Chitina Valley and possibly having a much greater extent than is yet known. Individual flows range in thickness from a few feet to several hundred feet, but the regularity of these flows is such as to give the greenstone the appearance of bedded sedimentary rock. Mineralogically, and texturally the basalt shows great similarity throughout the succession of flows and also in the individual flows. As a rule the tops and bottoms of flows are not distinguishable by textural features. Scoriaceous surfaces are not recognized, and gas cavities are not especially characteristic of the tops of the flows, although in a few localities this feature was noted.

The lava flows form hard, resistant rocks, and although everywhere chemically altered from their original condition, they are much less soluble than the overlying limestone. They have been folded in the same way and at the same time as the limestone but have reacted differently to the deforming forces. They have accommodated themselves to deformation in part by bending and faulting but still more by breaking into innumerable blocks of various sizes bounded by fracture planes whose slickensided surfaces show movement of one block on another, even where well-defined fault planes are not present. Such fractures provided most intricate channels for the circulation of mineral-bearing waters.

In the greenstone deposits are found bornite, chalcopyrite, pyrite, chalcocite, malachite, azurite, native copper, silver-bearing tetrahedrite (possibly in part freibergite), cuprite, covellite, and chalcanthite, of which bornite, chalcopyrite, chalcocite, and pyrite are most abundant. The copper minerals are accompanied in many places by quartz, epidote, and calcite.

A study of a large number of prospects in the Kotsina-Kuskulana district led to a separation of the copper sulphides in greenstone into the following classes:[5]

Argentiferous tetrahedrite ores.
Chalcocite ores.
Bornite and bornite-chalcocite ores.
Bornite-chalcopyrite ores.
Pyrite-chalcopyrite ores.

These associations of minerals apparently represent the original character of the deposits, and in the few places where other copper minerals were found with the minerals in one of the above-named classes it was fairly certain that the extra minerals were of later origin.

A few of the copper deposits take the form of well-defined veins of considerable extent. Such veins are found in the Strelna formation as well as in the Nikolai greenstone. By far the greater number of copper deposits are of the stockwork and disseminated types. Mineral-bearing solutions in circulating through the greenstone along available openings have deposited copper minerals and to a certain extent have replaced the greenstone. These solutions also penetrated into the greenstone walls adjacent to the channels and deposited copper minerals that have no evident connection with the main veins. In this way copper deposits were formed that are notably irregular in form and uncertain in extent.

The copper filling in the vesicles of lavas is chiefly native copper. These amygdaloidal copper deposits are found at several localities, of which the best known is that on Shower Gulch, at the head of Kotsina River. Native copper is also found as thin sheets or as slugs and irregularly shaped masses mingled with quartz in veins in the greenstone. In such places it appears to have resulted from the alteration of earlier copper minerals. A third mode of occurrence of native copper is with gold and silver in some of the stream gravels. Placer copper has been found wherever streams cutting rocks of the Nikolai greenstone have been worked for gold and is present in pieces that range in size from small shot to masses of several hundred pounds or at one locality even more than a ton. In the Nizina district copper has been recovered from the gold placers and shipped to the smelters but has not been found in paying quantities in bedrock.

Silver-bearing tetrahedrite is known at only one locality on Kotsina River, where it occurs in a vein with chalcopyrite, galena, and a small amount of bismuth-bearing mineral, probably bismuthinite.

[5] Moffit, F. H., and Mertie, J. B., The Kotsina-Kuskulana district: U. S. Geol. Survey Bull. 745, p. 86, 1923.

The copper deposits in greenstone are believed to have undergone weathering and possibly alteration during the same period as the deposits in limestone. Like the deposits in limestone, they have not been shown by mining development to change in character as they are followed downward. No reason exists, therefore, for supposing that copper deposits exposed at the surface will become either richer or poorer below the surface. The surface exposures are dependent on the accidents of erosion, which may have progressed only so far as to expose the beginning of an ore body or which may have exposed a maximum cross section or removed all but the last traces of the body. The first two possibilities are well illustrated by the conditions at Kennicott. When the Bonanza mine was discovered a large section of the ore body was exposed at the surface, and hundreds of tons of high-grade ore that had been eroded from the exposed vein lay in the talus on each side of Bonanza Ridge. The deposit at the Jumbo mine, on the other hand, was little more than indicated by surface exposures, and not until mining had proceeded for some time was the immense size of that ore body disclosed.

GOLD.

Gold has been produced in Chitina Valley from both lode deposits and placers. The production from the lode deposits, however, is insignificant in comparison with that from the placers, and such gold as has been obtained from lodes so far has cost more than its market value.

Gold-bearing veins are known in rocks of the Strelna formation; in the Valdez group, which lies south of and adjacent to rocks that are correlated with the Strelna formation in Hanagita Valley and the mountains between Copper River and Tonsina Lake; and in the Cretaceous shales of the Nizina district.

It is believed that the gold was deposited during at least two periods, of which one was earlier than that of the Upper Jurassic (?) rocks east of Kuskulana River and the other necessarily later than that of the Upper Cretaceous shales inclosing the veins of the Nizina district. Possibly other periods are also represented. Evidence for a period of gold deposition earlier than Upper Jurassic is not complete. Possibly the gold-silver veins of Berg Creek are not connected with the contact-metamorphic copper deposits near by on MacDougall Creek but are of later age. If this is true the gold deposits may eventually prove to belong to only one period.

All the gold veins so far discovered occur in rocks that are cut by granodioritic intrusives, and although the dependence of one on the other has not been demonstrated, the association is thought to be

significant. Mertie [6] has shown the existence of such a relation in the Yukon and Kuskokwim regions, and its existence in this district is probable.

The gold-bearing veins have not been explored sufficiently to warrant a separation into distinct types, yet differences in manner of occurrence are apparent. The silver-gold deposits of Berg Creek have been mentioned. They occur as veins of iron and copper sulphides with a little quartz and are found in a body of porphyritic granodiorite. Pyrite is the prevailing sulphide, but chalcopyrite is present and shows an iridescent stain where weathered. Mill tests have shown that the richest ore comes from oxidized parts of the veins and that silver predominates largely in quantity over the gold.

A promising gold vein on Benito Creek near the trail from Strelna to Elliott Creek consists of quartz and a subordinate quantity of coarsely crystalline calcite, with which are associated chalcopyrite, bornite, pyrite, and free gold. Stains of azurite and malachite have resulted from the oxidation of the copper sulphides. This vein is in rocks of the Strelna formation.

The gold-bearing veins of the Valdez group, such as those found along the lower Copper River and the Valdez road, consist of quartz carrying arsenopyrite and free gold. Galena is present in places. These veins cut slate and graywacke and are associated with light-colored dikes of diorite porphyry. Some of them have yielded small quantities of rich gold ore, but development work has always shown that the high-grade ore is irregularly distributed. Although such ores have furnished fine specimens, no considerable quantity of gold has yet been found, and none of the deposits have been worked profitably.

The gold-quartz veins in the Cretaceous shales of the Nizina district contain pyrite and free gold with locally some molybdenite and probably some stibnite. Galena, cinnabar, barite, and marcasite may also be present, for they are found in the creek gravels. A small vein on Rex Creek was found to consist of quartz with molybdenite and pyrite and assayed 0.18 ounce of gold and 12.80 ounces of silver to the ton. A dike rock near this vein seemed little altered and contained pyrite with traces of both gold and silver. These occurrences are cited to show the evidence for a local source of some of the gold in the creek gravels and to indicate that prospecting for gold lodes may be justified.

Gold placers in this district have been mined profitably only in the drainage basins of Dan and Chititu creeks and on a tributary to the north branch of Bremner River south of Chitina Valley.

[6] Mertie, J. B., The occurrence of metalliferous deposits in the Yukon and Kuskokwim regions: U. S. Geol. Survey Bull. 739, pp. 149–165, 1922.

In the Dan-Chititu area the placer gold has been derived from gold-bearing veins in the Cretaceous shales, and in the Bremner area from veins in rocks of the Valdez group, some of which have been prospected.

The gold of Dan and Chititu creeks and their tributaries is associated with native copper and native silver. Native copper, however, does not accompany the gold on tributaries like the upper part of Rex Creek, where the Nikolai greenstone is not exposed and where foreign gravels derived from the greenstone farther east in Chitina Valley were not brought in by the glaciers.

One feature of the gold placers that deserves special consideration is that the most productive gravel is that in which a concentration of gold from bench gravel has taken place. The deep bench gravel of both Dan and Chititu creeks contains gold. Prospecting tunnels have been driven in numerous places to test this gravel, and it has been mined on both Dan and Chititu creeks. The bench gravel itself may contain older creek gravel with concentrations of gold. A well-defined old channel considerably above the present creek level follows the mountain slope south of Dan Creek. Its buried creek gravel carries gold and has been mined in a small way for a number of years.

Most of the gold in the bench gravel is concentrated near bedrock or in places on "false bedrock" at different distances above true bedrock. It is only these richer parts of the bench gravel that have been mined. Possibly the upper part of the bench gravel is too poor to be mined for its own gold content, so that the cost of its removal must be borne by the lower and richer gravel when the time comes for exploiting the benches.

The deep bench gravel was trenched and parts of it were removed or are being removed by the present streams. During this process the gold in the reworked gravel received a further concentration, with the result that the creek gravel is much enriched. Reconcentration of gold from the deep bench gravel into present stream gravel is common in many parts of Alaska, and the knowledge of this process should lead the prospector to give special attention to those localities where streams are seen to be reworking bench gravel.

SILVER.

The occurrence of silver has been mentioned in considering copper and gold. Silver occurs in this district in association with the copper ores of Kennicott, where it is present to the amount of 14 to 16 ounces to the ton of high-grade ore; in the pyrite-chalcopyrite veins on Berg Creek; in the tetrahedrite veins on Kotsina River; and as native silver associated with native copper and gold in the gold placers of

the Nizina district. Samples taken from gold-bearing veins in different parts of the district commonly contain some silver.

For the purpose of this paper it is not necessary to discuss the silver recovered in smelting the copper ores of Kennicott, as that is plainly a by-product of copper mining.

The claims on Berg Creek were staked and prospected for copper, but the veins now being mined were found on exploration to be worth more in gold and silver than in copper. Later, when the mill was started, it was learned that silver predominated largely in quantity over the gold.

Silver is the only metal in the silver-bearing tetrahedrite veins of Kotsina River that may have a commercial value, but exploration of the veins has not progressed to the stage where their value has been demonstrated. The veins are apparently in rocks of the Strelna formation but are close to the Nikolai greenstone and not more than a third of a mile from a mass of granodiorite which intrudes the Strelna rocks. The country rock inclosing the deposits is much shattered and faulted. The veins consist of a quartz gangue containing tetrahedrite, galena, azurite, and malachite. Bismuth is present in tiny veinlets of bismuthinite (?) cutting the tetrahedrite. No similar veins have been found elsewhere in Chitina Valley.

Nuggets of silver and also of copper and silver ("half breeds") are frequently found in the sluice boxes on Dan and Chititu creeks. One of the largest silver nuggets from the Nizina district known to the writer was found on Chititu Creek and consisted of a mass of native silver and quartz weighing 7 pounds. Other large nuggets have been found, and some of them may have been even larger than the one mentioned. Silver is not likely to be produced from placers in this district except as a by-product in the mining of placer gold. No evidence is known to indicate that silver is anywhere present in commercial placers. Doubtless the copper will be sought in the placer gravel before silver, if it ever becomes profitable to mine either metal where gold is not present.

SUMMARY.

Copper, gold, and silver are being mined in Chitina Valley. Practically all the copper so far produced has come from deposits in the Chitistone limestone at Kennicott. Practically all the gold has been taken from the gold placers of Dan and Chititu creeks. Silver is an important constituent of the ores from Kennicott, is present in the gold placers, and has been recovered from one vein deposit.

The only producing copper mine is in the basal beds of the Chitistone limestone, but copper deposits also occur in the basaltic lava flows of the Nikolai greenstone and in similar basaltic lavas of the

Strelna formation, which underlies the Nikolai. Experience gained from mining and from a consideration of the known occurrences of copper minerals indicates that the most favorable horizon in the Chitistone limestone for copper deposits is in the beds near the Nikolai greenstone. This conclusion, however, is not universally applicable, for the original outcrop of the Mother Lode mine, now being exploited by the Kennecott Corporation, was many hundreds of feet stratigraphically above the base of the limestone, possibly near the middle of the formation. A few copper deposits in greenstone occur as well-defined fissure veins, but by far the greater number were formed by the deposition of copper minerals in preexisting openings or by the replacement of the wall rock along irregular and intricate systems of fractures.

Gold and silver are found in the formations ranging from the tuff, limestone, shale, and basalt flows of the Strelna formation to the Cretaceous shales. Gold is produced chiefly from placer gravel, and silver from the silver-bearing copper ores of Kennicott, but both metals are being produced from vein deposits, so that the expectation of finding other gold-silver veins is reasonable. The probable dependence of gold-silver mineralization on the intrusion of granodioritic rocks should be kept in mind in prospecting for placer deposits as well as for veins.

Prospectors searching for copper or gold lodes in this district should not expect a necessary or probable increase in the value of ore deposits at depth, for in general the original zone of oxidation and enrichment was largely removed during the period of intense glaciation. The depth of the ore body and the vertical distribution of high-grade ore are likely to depend primarily on the accidents of erosion. The richest part of the lode is as likely to be exposed at the surface as the poorest.

Furthermore, the prospector for placer gold should pay particular attention to deep gravel which is being reworked by present streams, for this process at many Alaskan localities has resulted in a reconcentration of low-grade deposits and the formation of valuable placers.

GEOLOGY AND MINERAL RESOURCES OF THE REGION TRAVERSED BY THE ALASKA RAILROAD.

By Stephen R. Capps.

INTRODUCTION.

On the completion of the bridge across Tanana River, in March, 1923, the Alaska Railroad, begun in 1915, was opened for direct traffic between Seward, on the Pacific coast, and Fairbanks, in the heart of central Alaska, a distance of 468 miles (fig. 1). Rarely has

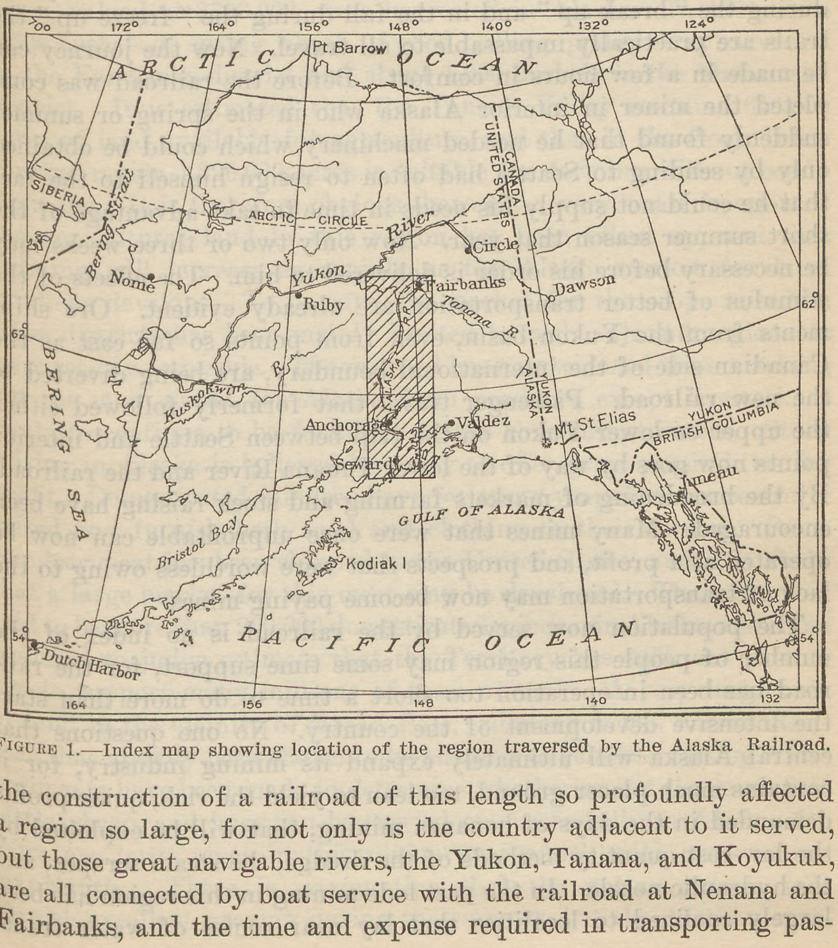


Figure 1.—Index map showing location of the region traversed by the Alaska Railroad.

the construction of a railroad of this length so profoundly affected a region so large, for not only is the country adjacent to it served, but those great navigable rivers, the Yukon, Tanana, and Koyukuk, are all connected by boat service with the railroad at Nenana and Fairbanks, and the time and expense required in transporting pas-

sengers and freight to the basins of these streams have been greatly decreased. Perhaps the advantages of direct rail connection with the coast will be appreciated by none so much as by the pioneers of the Yukon basin, who, in spite of the handicaps of slow river transportation in summer and almost complete isolation in the winter, have endeavored to develop the resources of the basin. A few years ago the Fairbanks mining man who had purchased supplies in Seattle during the winter or spring was unable to land them on his property much before the end of June, for it required three weeks or more to make the journey by way of Skagway and the upper Yukon, and that river is not navigable until it runs free from ice in the spring. Now it is possible to land a shipment at Fairbanks in half that time from Seattle at any season of the year. Not long ago the trip from Nenana to Seward by way of Broad Pass meant weeks of severe physical exertion over a trailless country by pack train in summer, or a hard, long trip by dog sled in winter. For weeks in the spring during the "break up" and in the fall during the "freeze up" the trails are practically impassable to all travel. Now the journey can be made in a few hours in comfort. Before the railroad was completed the miner in interior Alaska who in the spring or summer suddenly found that he needed machinery which could be obtained only by sending to Seattle had often to resign himself to the fact that he could not supply his needs in time to take advantage of the short summer season that year. Now only two or three weeks may be necessary before his order is delivered to him. The effects of the stimulus of better transportation are already evident. Ore shipments from the Yukon basin, even from points so far east as the Canadian side of the international boundary, are being diverted to the new railroad. Passenger travel that formerly followed either the upper or lower Yukon on the trip between Seattle and interior points now goes by way of the lower Tanana River and the railroad. By the broadening of markets farming and stock raising have been encouraged. Many mines that were once unprofitable can now be operated at a profit, and prospects that were worthless owing to the lack of transportation may now become paying mines.

The population now served by the railroad is no index of the number of people this region may some time support, for the railroad has been in operation too short a time to do more than start the intensive development of the country. No one questions that central Alaska will ultimately expand its mining industry, for it contains much placer ground, too lean to yield the rich, quick profits demanded in the days of bonanza mining, that will be exploited by the low-cost quantity methods of the dredge, the steam scraper, and the hydraulic nozzle. In the past lode mining in this region has been largely confined to localities that lay near routes of water trans-

portation. The cost of transporting heavy machinery and supplies in a roadless country was too great to be borne by small lodes of medium grade. Now rail transportation will make it possible to place mining and milling machinery on lodes that have heretofore not warranted such an expenditure. The agricultural population of this region, however, may sometime outstrip in numbers that employed in mining. Mineral resources, even in a country rich in its mineral deposits, are exhaustible, whereas farm lands may produce indefinitely. It so happens that the Alaska Railroad touches the two districts in Alaska that are farthest advanced in their agricultural development—the Knik Arm-Matanuska district and the Fairbanks district. In each of these districts it has been conclusively demonstrated, by farming for several successive years, that properly selected crops can be matured, that stock can be raised, and that a livelihood can be gained by tilling the soil.

The 1920 census report shows that in 1919 crops from 4,473 acres, valued at $393,902, were harvested in Alaska. In 1921 some 3,500 bushels of spring wheat, of good milling quality, was harvested in the Fairbanks district and about 1,000 bushels in the Matanuska district. It is estimated that the Tanana Valley contains 640,000 acres of land available for agriculture, and that in the Cook Inlet-Susitna region 1,296,000 acres is suitable for farming without costly drainage. It is therefore obvious that only a very small fraction of the agricultural land in this region has been taken up, and that farming will increase as rapidly as the Alaska market for farm products develops. To be sure, the market for the crops raised in these districts has been mainly limited to such adjacent regions as were readily accessible. The railroad has now widened these markets, but the main outlet for Alaska farm products, except livestock, is likely to continue to be found in Alaska consuming centers. Stock raising in Alaska is believed by many to offer great possibilities for profit. Domesticated reindeer have for many years been successfully raised and furnish both food and clothing to their owners. Some reindeer meat has been shipped to the United States, and it is likely that a large market for this meat may be developed. There are now said to be more than 200,000 domesticated reindeer in Alaska, and those qualified to judge estimate that the Territory has sufficient pasturage to support many millions of these animals. A very large area of land in the vicinity of Broad Pass, tributary to the Alaska Railroad, has already been shown to be adapted to reindeer raising. Experiments have been made to determine whether or not the raising of cattle, sheep, and hogs can be carried on successfully in Alaska, for there are large areas in this region over which wild grass grows luxuriantly. There is no question that the native grasses will furnish excellent grazing during the summer, but the Alaskan sum-

mer is short, and the winter season, during which the animals would have to be fed, is long. It is likely that in time, by breeding hardy types of animals and by the use of ensilage made from wild grass, that cattle, hogs, and sheep can be raised successfully in favorable places in the Territory.

The mining industry within the region tributary to the Alaska Railroad is certain to expand under the present improved conditions of operation and marketing. In fact, the operation of the coal mines of the Matanuska Valley and of the smaller mines along the railroad route was impossible until rail transportation was available, for the railroad furnishes the only means of moving the coal to market and at present is itself the principal consumer of the coal produced. It is expected that eventually the Matanuska mines will supply coal for coaling stations on the Pacific, to serve vessels in the trans-Pacific and coastwise trade, and thus support a greatly increased mining population.

It is not yet possible to predict accurately which metal-mining regions will be the first to respond in a large way to the stimulus of railroad transportation, but many districts have already been greatly helped, and the beneficial effect will be cumulative. The Willow Creek gold lode district has always profited by its accessibility to water transportation during the summer but now has the added advantage of year-round transportation by rail. The Yentna district, always hampered by high freight costs and by a bad summer trail, can now be reached at any time over a road from the railroad at Talkeetna. The Iron Creek prospects, in the Talkeetna basin, heretofore too remote for development at a reasonable cost, can now be made accessible by a road, some 40 miles in length, from Talkeetna. Similarly, the lode district of the West Fork of Chulitna River, the Valdez Creek gold placer district, and the placer and lode mines of the Nenana basin and the Kantishna district are all greatly helped by the completion of the railroad, but they will receive the fullest possible benefit only when wagon roads connecting the mineral deposits with the railroad are completed. The Fairbanks district is already enjoying the advantages of frequent and easy contact with the coast and lower freight charges, and to a lesser degree these advantages extend to all the central Alaska mining districts that are connected with the railroad through the Yukon and its navigable tributaries. The Tolovana gold placer district is now indirectly connected with the railroad by wagon road and boat service, and the Hot Springs district, which contains gold placers and promising tin deposits, will profit by its steamboat connection with the railroad. As a whole, the area served directly and indirectly by the new railroad is rich in mineral wealth. Under the primitive transportation facilities of the past this area has produced minerals worth

$160,000,000. In 1922 the country immediately tributary to the railroad produced gold, silver, and coal worth $2,034,210 and in addition a small amount of lead, copper, and tin, and if the larger area indirectly benefited by the railroad is included, the production of minerals in 1922 was worth over $3,000,000.

Gold mining has been carried on in Kenai Peninsula for many years. In 1922 the output was about $40,000.

The Willow Creek lode district, north of the head of Knik Arm, has produced over $2,000,000 worth of gold in the last decade and in 1922 yielded $239,500 in gold and silver. The Matanuska coal field, served directly by a branch line of the railroad, yields a high-grade coal for railroad and industrial uses. The Yentna placer district, now connected with the railroad by wagon road from Talkeetna, produced gold worth $223,000 in 1922. There are many promising undeveloped copper and gold lodes in the Talkeetna Mountains and the Alaska Range south of Broad Pass, and gold placer gravels have long been mined in the Valdez Creek district.

The railroad crosses the Nenana lignite field, whose reserves are estimated at over 9,000,000,000 tons. Already coal from this field has reduced the cost of mining in adjacent districts. The Kantishna district, 60 miles west of the railroad, has valuable placer-gold deposits, as well as promising gold, silver, and lead lodes.

The Fairbanks district, at the inland terminus of the railroad, has since its discovery produced $73,686,976 worth of minerals, mostly in placer gold but including lode gold, antimony, tungsten, silver, and lead. Its gold output in 1922 was valued at $693,000.

In 1922 the Tolovana district produced minerals worth $222,000, and the Hot Springs district $55,000, mainly placer gold.

The completion of the railroad will greatly benefit both Alaska and the general public by making the Mount McKinley National Park accessible to travelers. This great park, established in 1917 and enlarged in 1922, now includes an area of over 2,600 square miles, comprising that portion of the Alaska Range that culminates in Mount McKinley, 20,300 feet above sea level, the loftiest peak on the continent. Flanking Mount McKinley to the south and east are great numbers of unnamed and unexplored snow-capped peaks, drained by a multitude of glaciers. The crest of the range is approachable from the north through many delightful valleys, the natural range of thousands of bighorn sheep and caribou, numerous bear and moose, and a great variety of fur-bearing animals. This park affords the visitor a remarkable opportunity to study a section of our fast disappearing wilderness, here fortunately preserved before the approach of civilization had brought about the destruction of its wild life. The east edge of this park lies close to the

railroad in Nenana Valley, and the construction of a single road already projected from the railroad to the Kantishna mining district will make easily accessible 100 miles of a magnificent mountain range, a score or more of sheltered valleys, numberless unconquered peaks and glaciers to call the mountaineer, and a familiar contact with many of our noblest big-game animals. As a permanent asset to the Territory of Alaska and to the Nation, this park is likely to exceed in value even the richest of the mining districts, for all mines will sooner or later be exhausted, but the usefulness and value of such national recreation grounds will increase indefinitely throughout the years.

Although the railroad has already greatly improved transportation throughout a great area in central Alaska, its benefits to the Territory and its opportunities for usefulness are still limited by the difficulties of travel to the railroad from the many outlying mining and agricultural districts. As constructed, the railroad traverses a wilderness that was almost entirely devoid of trails and roads. Until roads are built from the mines and farms to the railroad the products of these districts can not move freely, and the railroad can not fully meet the needs for which it was designed. A vigorous program of road construction has been started by the Alaska Road Commission, the Bureau of Public Roads, and the Territorial Road Commission, and although much still remains to be done, many roads are already completed or well advanced.

In past years the casual tourist to Alaska has been limited to travel by the few routes over which he could procure regular transportation, and these routes were largely water routes. From Seattle regular steamship schedules were maintained along the coast by way of the "inside passage" to Skagway and thence westward to Prince William Sound and Cook Inlet ports. From Cordova the Copper River & Northwestern Railway runs inland 196 miles to the Kennecott mines, and from that railroad at Chitina a road, over which an automobile stage was operated in summer and a horse-drawn stage in winter, extended to Fairbanks. From Skagway the White Pass & Yukon Railroad crosses the mountains to the headwaters of Yukon River, and on that river and its larger tributaries there was regular steamboat service during the ice-free season. Summer service was also maintained by steamship from Seattle to Nome. The regular steamship routes were supplemented by smaller boat lines at various places. It will thus be seen that the only regular main lines of transportation in Alaska were confined to boat service on the coast and on the larger navigable rivers, except for the Copper River & Northwestern Railway, and the stage road between Chitina and Fairbanks. During the winter steamship sailings to Bering

Sea and upper Cook Inlet ports and all boat service on the rivers are suspended on account of ice.

The opening of the Alaska Railroad has now made possible an easy summer tourist trip that includes a great variety of scenery and a large area of country, a trip that could formerly have been made only at a much larger expenditure of time, money, and effort. The traveler can now leave Seattle or Vancouver on a comfortable ocean steamer and journey northwestward along the "inside passage" past Vancouver Island and through the picturesque and rugged Alexander Archipelago to Skagway, the ocean terminus of the White Pass & Yukon Railroad. A daylight trip of 112 miles across the coastal mountain range will bring him to the town of White Horse, Yukon Territory, at the head of river navigation in the Yukon basin. There river steamboats begin the long downstream journey through Lake Lebarge and Lewes River to the Yukon, past the mouth of the turbid, glacier-fed White River to Dawson, at the mouth of Klondike River. Continuing downstream he stops at the old settlements of Fortymile, Eagle, and Circle and crosses the Arctic Circle at Fort Yukon, at the great northern bend of the Yukon. From Fort Yukon the river flows in many branching channels through the Yukon Flats to the site of old Fort Hamlin, whence, once more confined to a single deep gorge bordered by high rock bluffs, it follows its devious course to the town of Tanana, at the mouth of Tanana River. At this point the route leaves the Yukon and ascends its largest tributary, the Tanana, to Fairbanks, the center of the great Fairbanks gold-mining district and the largest town of interior Alaska.

All the journey just outlined has been possible for the last 25 years, but to complete the trip from Fairbanks back to Seattle has heretofore required either a slow upstream return journey by the same route; a continuation of the down-Yukon trip through monotonous lowlands to the river mouth and St. Michael, thence to Nome, and by ocean steamer to Seattle; or a stage journey by automobile or horse-drawn sled to Chitina, on the Copper River & Northwestern Railroad, and thence by rail to Cordova and ocean steamer to Seattle. Now the traveler can take the train on the Alaska Railroad at Nenana or Fairbanks and travel southward, stopping off if he desires at the Mount McKinley National Park, cross the Alaska Range through Broad Pass, and follow down Chulitna and Susitna valleys, with the Talkeetna Mountains on the left and the great sweep of the Alaska Range on the right, dominated by Mount McKinley, America's loftiest mountain. The traveler then goes around the head of Knik Arm through the agricultural lands of lower Matanuska Valley and thence southwestward to Anchorage, on Pacific

waters, a summer port on the long Cook Inlet embayment. At Anchorage alternate routes are available to Seward, either by continuing the railroad journey through the Chugach Mountains, skirting Turnagain Arm and going through the Kenai Mountains and past great valley glaciers to Seward, or by taking an ocean steamship down Cook Inlet and around the shores of Kenai Peninsula. From Seward coastwise vessels call at Prince William Sound ports, skirt the base of Mounts St. Elias and Fairweather, with their great piedmont glaciers, and enter the inside passage through Icy Straits, to return by the route already outlined past Juneau, Wrangell, and Ketchikan.

The trip here suggested, comprising a great loop, has the advantage of giving the traveler in a single journey at least a glimpse of the many varied types of country, climate, and vegetation to be found in Alaska. He leaves the heavily timbered islands of the coastal region, with its temperate and somewhat rainy climate, to cross the rugged snow-capped coastal mountains and enter the dry sunny valleys of the interior. The Alaska Range offers splendid glaciated mountains teeming with wild life; the Susitna basin reveals wide timbered lowlands with lofty bordering ranges; and the coastal mountains with their intricate fiords, tidal glaciers, and towering snow peaks present the forbidding barrier along the ocean front that has so long helped to establish the common misconception that Alaska is entirely a forbidden land of mountains, ice, and snow.

GEOGRAPHY.

In the journey from Seward, at the coastal terminus of the Alaska Railroad, to Fairbanks, the inland terminus, the traveler passes through parts of at least six distinct geographic and geologic provinces and near the edge of a seventh. These provinces differ from one another in the essential features of surface form, climate, soil, and vegetation, as well as in geology and mineral resources. As each of these features has a direct bearing upon the proper utilization of any area, and as the combination of them in each particular district will determine the kind and intensity of its future development, it seems proper to describe these provinces separately.

CHUGACH AND KENAI MOUNTAINS.

For the last 18 miles of the voyage from Seattle to Seward the steamship travels northward up the narrow embayment of Resurrection Bay, a glacial fiord that heads well back in the rugged Kenai Mountains. These mountains, together with their northward and eastward extension, the Chugach Mountains, and the St. Elias Range, still farther east, form the great coastal barrier that gives Alaska

so forbidding an aspect as viewed from the Gulf of Alaska. These coastal ranges are characterized by high, rugged peaks and extensive snow fields and glaciers, and on Prince William Sound and southeastern Kenai Peninsula by an extremely irregular and intricate shore line indented by deep and narrow glacial fiords. Some of the largest North American ice fields, Malaspina and Bering glaciers, the St. Elias ice cap, and the great ice cap southwest of Seward, lie in this belt, and at many places great ice lobes push down to tidewater and discharge bergs into the sea. The steamship voyage along the rim of the Gulf of Alaska in clear weather gives a panorama of magnificent subarctic mountains and glaciers that can scarcely be matched elsewhere.

The climate on the immediate border of the Gulf of Alaska is surprisingly mild, for it is tempered by the nearness of this area to the warm Pacific waters. At Cordova the winter temperature in many years does not fall to 0° F. At a short distance back from the coast and into the mountains, however, there is a great change in the climate, with much more severe winters. The coastal mountains in general have a heavy precipitation, and much of it falls as snow, which accounts for the much greater development of glaciers near the coast than in equally high mountains in the interior. From Resurrection Bay and the Alaska Railroad the great ice cap of Kenai Peninsula is indicated mainly by the glacial tongues that stretch down toward tidewater from it. In northern Kenai Peninsula, however, the railroad passes close to the foot of two fine valley ice lobes, Bartlett and Spencer glaciers, and within sight of Portage Glacier.

The name "Kenai Mountains" is used to designate the mountains on Kenai Peninsula, which is limited on the north by the constriction between Turnagain Arm and Portage Bay. The position of these bays, however, is due merely to the accidents of glacial erosion, the Chugach Mountains, to the north, and the Kenai Mountains being continuous with one another in both the character and the structure of their rocks. They are here included as belonging to a single geographic province.

On the journey inland from Seward the traveler goes northward some 50 miles through the Kenai Mountains to Turnagain Arm, encircles the head of that embayment, follows the abrupt and cliffed shore of the Chugach Mountains, and leaves the mountains to enter the second geographic province, the Cook Inlet-Susitna lowland.

COOK INLET-SUSITNA LOWLAND.

The Cook Inlet embayment, including Knik Arm, is an arm of the Pacific that extends 200 miles into the body of Alaska and with the lower portion of the Susitna basin constitutes a great structural de-

pression bordered on all sides except the Pacific by high mountains. This depression, including the inlet itself and the bordering low-lying areas, is here termed the Cook Inlet-Susitna lowland. It forms a province distinct in topography, soil, vegetation, climate, geology, and possibilities of development from the surrounding mountainous areas and is one of the most promising areas in Alaska for agriculture and stock raising.

In contrast to the bordering mountains, which are composed of hard rocks, the underlying materials in this lowland are mainly unconsolidated or only loosely cemented (Pl. I), so that the land forms take on smoothed, rounded shapes generally free from sharp peaks and abrupt slopes. The late geologic history of the lowland is that of constructive rather than destructive agencies, for the lowland has received the land waste removed from the surrounding highlands by streams and glaciers. The bench lands and inter-stream areas are largely floored with unstratified glacial débris and with gravel left as outwash from the great glaciers that formerly filled this basin. Aggradation or filling is still actively in progress in upper Cook Inlet through the discharge into tidewater by Susitna, Matanuska, Knik, and many other rivers of large quantities of gravel, sand, and silt, supplied to these streams by the glaciers in which they head. In this way upper Cook Inlet is slowly being filled in, the deltas of the larger rivers are creeping seaward, and the lowland areas are being enlarged at the expense of the water areas. This slow shrinkage of the area of Cook Inlet is somewhat offset by the wave activity in cutting back the shore cliffs in places, but the result of wave cutting also is to fill in the low places of the basin, with a constant though slow reduction in the volume of salt water in the Cook Inlet embayment.

The traveler going through this lowland by train gets the impression of an alternation of tracts of rolling country of moderate altitude, timbered by medium-sized spruce and birch trees and crossed at intervals by stream valleys trenched 100 feet or so beneath the general level, with broad open marshy tracts studded with lakes or ponds, containing only scattered groves and clumps of trees, and with ill-defined and shallow stream valleys. Around Knik Arm and in Matanuska Valley the land that has been cleared and developed for farming is for the most part high and fairly level bench land having a rather shallow soil overlying glacial outwash gravel. This land was naturally well drained and was easily cleared and prepared for the plow. In many large tracts, however, especially in the lower Susitna Valley, extensive drainage projects will be necessary before the land can be cultivated.

In certain well-drained portions of the lowland, especially near its upper edges and on the lower slopes of the surrounding mountains,

there is a remarkably luxuriant growth of native grasses, in thick stands that in places reach a height of 5 feet or more. This grass, under favorable weather conditions, can be cut and cured to hay of good quality and affords excellent forage for stock. Without doubt it will sometime be used for raising stock on an extensive scale.

Above the junction of Talkeetna and Chulitna rivers with the Susitna the Susitna lowland narrows, is broken by ridges of hills, and loses its basin-like aspect. The structural basin between the Talkeetna Mountains and their northward extension, on the east, and the Alaska Range, on the west, persists, however, to Broad Pass, though it can not there be properly termed a lowland.

TALKEETNA MOUNTAINS.

On the northward journey from Anchorage to Matanuska River the Chugach Mountains rise steeply on the right. At the town of Matanuska the main line turns westward, to skirt the west base of another range, the Talkeetna Mountains. The traveler can catch a glimpse eastward up Matanuska Valley, a prominent glaciated valley, without realizing that it marks the border line between two great mountain ranges, the Chugach on the south and the Talkeetna on the north. Indeed, if the question were to be decided upon surface forms alone, there seems to be less reason for separating the mountains on the two sides of this valley into separate ranges than for using Knik River valley or some other stream trough as a dividing line. A study of the geology, however, both as to the rocks themselves and as to their structure, shows that the Chugach Mountains and the Talkeetna Mountains are composed of very different materials, have had widely different histories, and have properly been given distinct names. The geology of the Talkeetna Mountains is described on pages 91–98, but it may be stated here that in the Chugach Mountains the rocks are dominantly of sedimentary origin and their general structure is parallel with the axis of the range, whereas in the Talkeetna Mountains the rocks are mainly igneous and have no pronounced structural trend. Erosion of these two classes of material has produced very different effects upon the topography, and the granitic rocks of the Talkeetna Mountains show an extremely rugged sky line, with sharp peaks and ragged, pinnacled ridges in the higher parts of the range.

Although glaciers exist in the headward portions of many valleys in the Talkeetna Mountains, this mountain mass lies behind the coastal barrier ranges and has a relatively light precipitation, so that its glaciers, as compared with the great ice fields of the coastal mountains, are small. The size of the present glaciers, however, is no measure of the effect that glacial erosion has exercised in

sculpturing the mountains to their present form, for the existing glaciers are only the shrunken remnants of the enormously greater ice fields that occupied this part of Alaska in glacial time. Then the Talkeetna Mountains were so deeply buried in ice and snow that only the highest peaks and ridges projected above the glacier's surface. At that time the entire basin of Susitna River and also the Copper River basin, to the east, were filled with enormous glaciers that extended well down the Cook Inlet depression. The movement of these great glaciers was largely controlled by the preexisting land forms, the ice in general following the valleys of the preglacial streams, but the erosive effect of these ice masses, hundreds and even thousands of feet thick and shod with effective grinding tools in the form of fragments, blocks, and boulders of rock, was profound. The mountains now retain a conspicuous glaciated topography, characterized by wide, open U-shaped valleys with hanging tributaries, glacial cirques and lakes, and many other evidences of the agencies by which they were sculptured.

COPPER-SUSITNA BASIN.

East of the Talkeetna Mountains lies another great basin region, of a complex geologic and physiographic history, many details of which still remain to be worked out. This basin is mainly tributary to Copper River, but a considerable area of its northwest corner drains into the Susitna, and a small portion to Bering Sea by way of the headwaters of Nenana River. This is not the place for a general description of the Copper River basin as a whole, for most of it lies east of the region here under discussion, but a considerable area in its northwestern part, mainly in the Susitna drainage basin, lies within this region. The headward tributaries of the main Susitna River derive their waters from the east and northeast slopes of the Talkeetna Mountains, from a portion of the south slope of the Alaska Range, and from a number of isolated groups of hills and mountains that rise through a broad expanse of glacial and alluvial deposits. The basin areas between and around these higher land masses can not properly be called lowlands, for their altitude ranges from 2,500 to 4,000 feet above sea level, but they are surrounded by much higher mountains, relative to which they are low. Their surface is generally more or less rolling, covered with scattered spruce timber, and dotted with a myriad of small lakes. In most places the major steams have intrenched themselves into the unconsolidated basin deposits. Like the Cook Inlet-Susitna lowland, the Copper-Susitna basin is mainly floored with detritus brought down to it by the glaciers that once poured into it from the mountains on all sides and with gravel laid down by the torrential streams that

drained from those glaciers. The details of the ancient drainage have not yet been worked out, but sufficient facts are at hand to suggest strongly that at some past time the upper Copper River basin, above Woods Canyon, drained to the sea by way of Susitna River, and the old course of the river valley may have been along the upper Nenana and Chulitna valleys. There is reason to believe that the present Susitna Valley for some distance above the mouth of Indian River is postglacial.

The relatively high altitude of this portion of the Copper-Susitna basin, with its shorter growing season and more frequent frosts, makes this area unpromising as farming land. It would, however, support many grazing animals in the summer season, and it is believed to have important possibilities as a range for reindeer.

ALASKA RANGE.

The Alaska Range comprises a great crescentic belt of rugged and glaciated mountains that sweep northward from the base of the Alaska Peninsula to Mount McKinley and extend thence eastward and southeastward, continued by the Nutzotin Mountains, to Canadian territory. As thus defined the range has a length of nearly 600 miles and an average width of 50 to 80 miles and so constitutes one of the great physiographic features of North America. It is visible on the west from the railroad throughout the Susitna and Chulitna valleys and is crossed by way of Nenana Valley between Broad Pass and Nenana. Of particular interest to the traveler is Mount McKinley, to be seen on clear days from favorable points in the Susitna and Tanana basins. This majestic snow-clad peak has an altitude of 20,300 feet, thus surpassing in height all other mountains on the continent. It forms the central object in the Mount McKinley National Park, which includes a great area of the finest scenery west of the railroad. In a general way the range forms the watershed between the southward-flowing Pacific Ocean tributaries and those that flow westward to Bering Sea, though some notable exceptions, including Nenana and Delta rivers, have headward tributaries that receive their waters from the south side of the mountains and cross the entire range through deeply cut valleys on their course to Tanana River.

On its north front the main Alaska Range is flanked by minor foothill ridges, separated from the main mountain mass by basin-like depressions. These foothill ridges lie parallel to the main range and were formed during the same general period of mountain building.

The higher parts of the Alaska Range, notably just south and east of Mount McKinley, are the gathering ground for some of the larg-

est Alaska valley glaciers. At least five of these great ice tongues are from 30 to 50 miles long and from 2 to 4 miles wide, and there are innumerable smaller ones, for the most part unnamed and unexplored. The present surface forms on this range are due in large part to the erosive action of these valley glaciers and of their enormously greater ancestors.

TANANA LOWLAND.

North of the Alaska Range lies a broad structural lowland basin that is continuous from Bering Sea by way of the Kuskokwim Valley northeastward across an imperceptible divide to the Tanana Valley and thence eastward across the Alaska-Canada boundary to the upper Yukon basin. This lowland ranges in width from 30 to 60 miles, has a gentle slope away from the range, and is broken only by a few isolated hills that rise above the general level of the plain. It is floored by unconsolidated materials, prevailingly gravel, that have been supplied by the erosion of the Alaska Range. It is likely that beneath the gravel there are extensive Tertiary deposits, which may contain lignite. Only the larger streams maintain well-defined channels across the lowland, the smaller tributaries sinking into the gravel to emerge again as sluggish, meandering creeks that drain the flat basin. The lowland surface consists of open marshy areas and lakes interspersed with patches of spruce and larch timber and is difficult to cross in the summer. In the area here considered Tanana River hugs closely the northern border of the lowland, for the major northward-flowing streams are glacier-fed and carry large quantities of gravel and silt, with which they have graded up the lowland. The tributaries of Tanana River from the north, by contrast, have low gradients and carry little detritus and have thus been at a disadvantage as compared with the heavily loaded streams from the south. As a result, the valley axis of Tanana River has been shifted northward and now follows closely the sinuous line formed by the base of the bordering hills on that side.

YUKON-TANANA UPLAND.

The part of the Yukon-Tanana upland that lies within the area here considered consists of smoothed and rounded ridges having a northeasterly trend and rising from flat lowlands by which the separate ridges are partly or entirely surrounded. The lowland is that of Tanana River and its sluggish northern tributaries, and its timbered and marshy surface has an altitude between 300 and 600 feet. Through this expanse of flat alluvial deposits the hard rock ridges project as islands or peninsulas with sinuous outlines. The crests of the ridges have altitudes of 1,000 to 3,000 feet, although

farther north certain peaks and domes project above the level of the upland surface to a height of nearly 5,000 feet. This area falls within the limits of the Yukon Plateau. The topography is mainly that developed in a region of highly metamorphosed and folded rocks by the agencies of stream erosion and deposition, glaciers having existed only as small ice tongues around the higher domes. There is no evidence of even local glaciation in the part of the Yukon-Tanana upland considered in this paper. The topography of the upland north of Tanana River is therefore in sharp contrast to that of the entire region south of the Tanana lowland, for there extensive glaciers have been developed at successive intervals and have been the controlling factor in producing the present topographic forms. North of the Tanana long-continued and uninterrupted stream erosion, influenced by the structure of the underlying rocks, has developed maturely dissected ridges and broad valleys that lie parallel to the trend of the prevailing rock structure. The surface is generally covered by a thick mantle of soil, humus, and rock-disintegration products, and outcrops of rock below the ridge crests are uncommon. The main stream valleys have wide floors and gentle gradients, and there is generally a thick filling of alluvium between the present stream beds and the underlying bedrock, especially in the lower courses of the streams.

GEOLOGY.

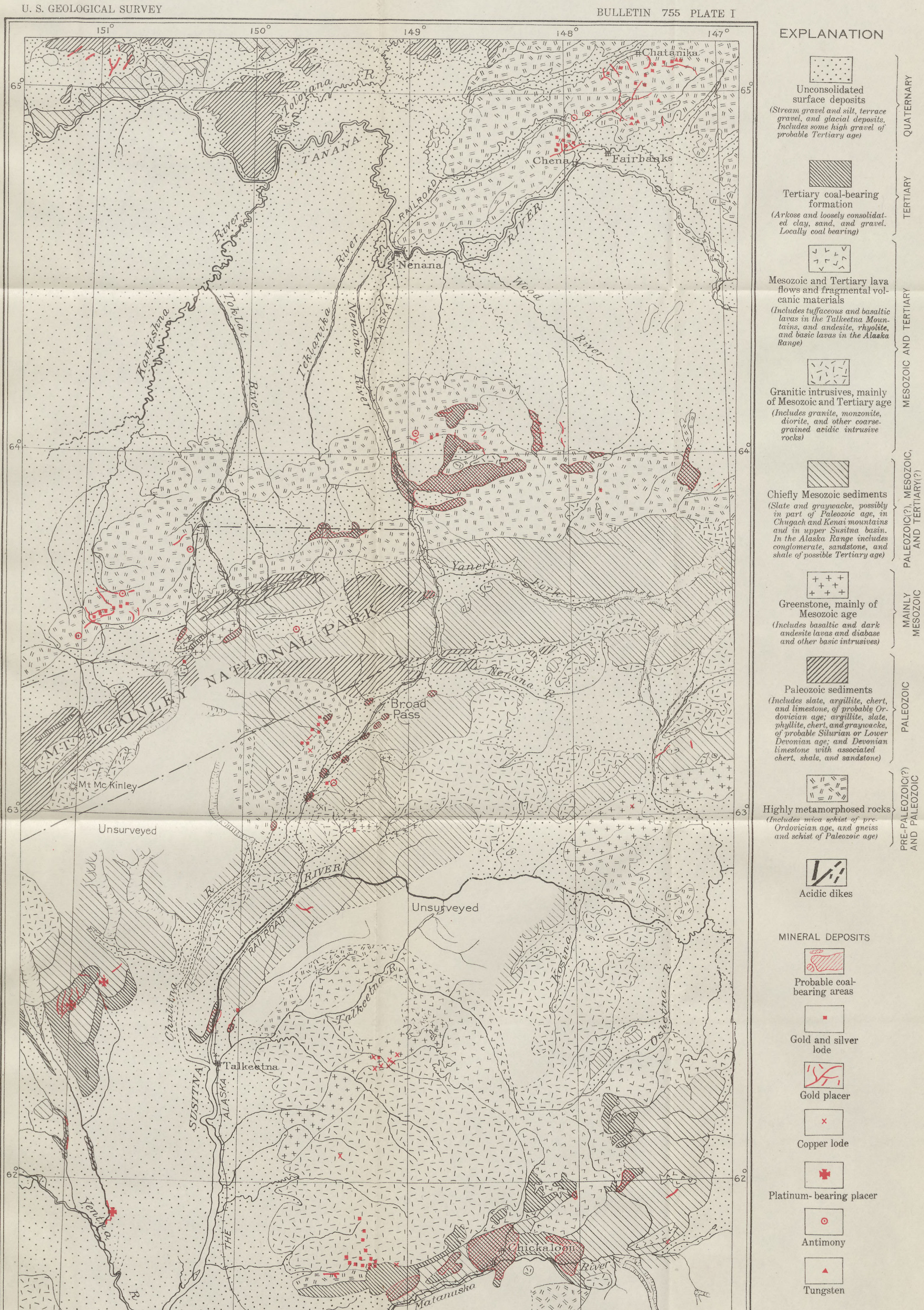
GENERAL FEATURES.

The mapping of the geology of the region tributary to the Alaska Railroad has been a long and difficult task and is still incomplete. Since 1898, when the work was started, a large number of geologists have contributed their work season by season, until now only a relatively few small areas remain in which the major geologic units have not at least been outlined. Most of the work, however, has been of reconnaissance character, in which the geologists covered as large an area as possible in the short working season, and refinements of mapping still remain to be made in much of the area. It should be remembered by future geologists, who will be able to reach any part of this region within a few days from the railroad, that most of the results shown on Plate I were obtained at a time when there was not even regular steamship service to upper Cook Inlet, when the common means of inland travel were small boats propelled by hand on the rivers or pack horses in the upland areas, and when throughout a large part of this region there was not even a trail to follow. In the exploratory work of these geologists a large part of each man's energy was consumed in overcoming the mere physical difficulties

of travel—chopping trail through the heavy brush, fording great rivers, or poling a boat upstream against the swift current. The person who realizes these facts will be less critical of the results here set forth than astonished that so much has been accomplished under conditions so difficult. In the present report the attempt is made to outline on the map (Pl. I) only a few of the great rock groups, in order to emphasize their relation to the mineral deposits of the region. The many geologic reports from which this paper is compiled have carried the subdivision of the rocks much further than is shown here. Anyone desiring more detailed information than is given here should apply to the Director of the United States Geological Survey for the latest report dealing with the district in which he is especially interested.

A study of the geologic map at once discloses the fact that most of this region is occupied by rocks of only moderate geologic age. The oldest rocks present are the mica schists that have generally been considered to be of early Paleozoic age, though it is not unlikely that they are pre-Cambrian. These rocks are present mainly on the north flank of the Alaska Range and in the vicinity of Fairbanks. Paleozoic rocks are rather scantily represented, for south of the Alaska Range only a few areas of undifferentiated metamorphic materials, probably of Paleozoic age, and some Devonian limestones are known. North of that range Paleozoic or older rocks are more abundant, occurring as extensive belts of mica schist, of less metamorphosed sediments, and of ancient lavas and associated sediments, all now greatly altered from their original state.

The prevailing rocks from Seward to Broad Pass are of Mesozoic age. They include great areas of slate, shale, and graywacke, some of which are of uncertain age, some fossiliferous sandstone and shale, a little limestone and quartzite, and large areas of basic lava and tuff. There are also great masses of granitic intrusive rocks that have penetrated the earlier Mesozoic materials as immense batholiths, such as that which forms most of the western Talkeetna Mountains, or as smaller scattered bodies. Tertiary rocks are also present in abundance and range in character from the hard, mountain-building conglomerate and shale of the Cantwell formation through basaltic lava and intrusive dikes and sills to the generally poorly consolidated sand, clay, and gravel of the coal-bearing beds. Widespread deposits of ancient gravel also belong with the Tertiary or early Quaternary. Quaternary deposits cover a large portion of the region and include the unconsolidated lowland deposits of the streams and shore lines and the glacial deposits. Stream, glacial, shore-line, and estuarine beds are being formed to-day at many places in the region.



MAP OF THE REGION TRIBUTARY TO THE ALASKA RAILROAD SHOWING GEOLOGY AND MINERAL DEPOSITS

10 0 10 20 30 40 MILES

1924

This region is naturally subdivided into six geologic provinces, which differ in assemblage of rocks, in structure, and in geologic history. These provinces are the Chugach and Kenai mountains, the Talkeetna Mountains and their northward extension to Broad Pass, the Alaska Range, the Yukon-Tanana upland, and the two lowland areas, the Copper-Susitna basin and the Tanana lowland. The four mountain provinces will be described separately, in the order above named, as that is the order in which they will be seen in a trip over the railroad from Seward to Fairbanks. During the last great time division, the Quaternary, the mountain masses all stood at approximately their present positions and present altitude, and the geologic events that took place, including the shaping of the surface forms by erosion and deposition and the great invasions of glacial ice, affected all this region to a greater or less degree. The Quaternary geology of the whole region will therefore be discussed as a unit, and that discussion will include the two lowland provinces, whose deposits are largely of Quaternary age.

CHUGACH AND KENAI MOUNTAINS.

The Chugach-Kenai province includes the portion of the Chugach Mountains north and east of Turnagain Arm and Portage Bay that falls within this region and the structurally continuous Kenai Mountains of Kenai Peninsula and its bordering islands. This province is therefore bounded on the north and west by Matanuska River and the Cook Inlet-Susitna lowland and on the east and south by Prince William Sound and the Pacific Ocean. These mountains are structurally continuous with the great belt of coastal mountains of southern and southeastern Alaska, to the east, and with Afognak and Kodiak islands, to the southwest. This part of the great coastal mountain range lies at the elbow or hinge where the trend of the range changes from a northwesterly direction through southeastern Alaska to a southwesterly direction in Prince William Sound, Kenai Peninsula, and Kodiak Island.

METAMORPHIC AND IGNEOUS ROCKS.

The Chugach and Kenai mountains are composed primarily of sedimentary rocks that show a wide range of character and varying degrees of metamorphism. In the region between Matanuska and Knik rivers there are considerable areas underlain by metamorphic rocks that originally consisted of such acidic igneous materials as andesite and andesite porphyry and of basic rocks including peridotite, dunite, gabbro, pyroxenite, and various tuffs and agglomerates. Likewise there are materials in this area that represent the metamorphic equivalents of argillite, graywacke, and chert. This

whole assemblage of materials has been severely altered by folding, faulting, and various metamorphic processes and has been cut by both basic and acidic dikes and sills.

The age of this group of metamorphic rocks is not known certainly, but they are older than the slate and graywacke that form most of this mountain range, which are believed to be Mesozoic. Nothing more can be said at present than that the metamorphic rocks just described are probably pre-Mesozoic and may even be pre-Paleozoic. They are here referred to as Paleozoic or older.

The main mass of the Chugach-Kenai mountains is composed predominantly of argillite, slate, and graywacke. The materials were deposited mainly as impure sand and mud; later they were cemented to shale and impure sandstone and then further altered during the folding of the mountains. They now appear commonly as hard shale, or argillite, and graywacke, or impure quartzite, although locally metamorphism has proceeded far enough to convert them to slate and schist. As a whole the rocks of this great mountain range, though composed dominantly of sedimentary beds, are almost entirely lacking in fossils by which the age of the beds could be accurately determined. The few fossils that have been found are either poorly preserved or are forms that are of doubtful value in correlation. In general, however, what evidence there is points to a Mesozoic age for much of the sedimentary rock of the Kenai and Chugach mountains. Possibly they contain considerable areas of Paleozoic rocks.

The lack of fossils, the succession of thick series of monotonously similar rocks, and the complex structure of these mountains together make the geology of this area so complicated that there still remains much to be learned about it. The series of argillite and graywacke must be many thousand feet in thickness, for it comprises the great bulk of a long range of mountains that is from 50 to 75 miles wide and has a vertical relief of more than 10,000 feet. In some sections the rocks seem to lie in rather simple folds. Elsewhere they are closely folded, crumpled, and contorted. The major structural features, however, are commonly parallel to the axis of the range.

In addition to the prevailing argillite and graywacke of the Chugach and Kenai mountains, conglomerate and limestone occur locally in minor amounts. Associated with these sedimentary materials there are in places large masses of greenstone and greenstone tuff that appear either interbedded with the sediments as flows or fragmental volcanic deposits, or cutting them as intrusive masses. The copper deposits of the region are generally associated with such greenstone bodies. Granitic rocks also intrude the sediments in many places, either as fairly large bodies or as dikes and sills. Both

the greenstone intrusives and the granitic rocks are probably of Mesozoic age, though of course somewhat younger than the rocks they invade. The greenstone flows and tuffs are obviously of the same age as the sediments with which they are interbedded.

TERTIARY DEPOSITS.

In the Chugach and Kenai mountains Tertiary deposits are entirely lacking, but on their western flank Tertiary coal-bearing beds crop out in the Cook Inlet lowland, in the southwest corner of the area shown on the accompanying map (Pl. I). These Tertiary beds are similar to those occurring in the Susitna basin and are described more fully in that part of this report dealing with the Tertiary deposits of the Talkeetna Mountains. They consist of soft shale and sandstone with lignite beds. It is likely that this coal-bearing formation has a considerably wider areal distribution beneath the unconsolidated surface deposits than is shown on the geologic map.

UNCONSOLIDATED SURFACE DEPOSITS.

Within the mountainous areas of this province the unconsolidated surface deposits, of Pleistocene and Recent age, are of relatively small volume and small areal extent, being confined for the most part to the floors of the stream valleys. It is not possible to show most of these small areas on a map of the scale of Plate I. Bordering the mountains on the west, however, there is an extensive low-lying area, the Cook Inlet-Susitna lowland, in which the surface is almost entirely covered by a mantle of unconsolidated materials, including morainal deposits left by the last great glaciers during their retreat, of outwash gravel deposited by streams beyond the edges of these glaciers, and of the sand, gravel, and silt of river valleys, beaches, and tidal estuaries. These materials vary greatly in thickness but in general are thick enough to cover and conceal the underlying rocks. As all the agricultural lands of this region occur in areas that are floored with these materials, their economic importance is great.

TALKEETNA MOUNTAINS.

The Talkeetna Mountains proper include the rugged area that is bordered on the west and north by Susitna River, on the east by the Copper River basin, and on the south by the Matanuska Valley. For convenience in description they are also here made to include the northern extension of the area above defined, comprising a number of more or less isolated mountain ridges between upper Susitna and Chulitna rivers. These mountains lie north and east of the

railroad all the way between Matanuska and Broad Pass, the railroad following the lowlands and valleys that flank the mountains on the west.

Geologically the Talkeetna Mountains are composed of a great variety of rocks of widely varying ages, but they differ from all other mountain ranges in this part of Alaska in the fact that they are composed mainly of igneous material (Pl. I).

PALEOZOIC OR OLDER ROCKS.

The oldest rock recognized in these mountains is a mica schist in the Willow Creek district, at the southwest corner of the mountain mass. This schist was probably once normal sedimentary rock, such as shale and sandstone, with which was associated some igneous material, but through a long history of successive periods of intense deformation it has been squeezed into contorted fissile rock and recrystallized until its original character is obscure. It has yielded some small gold placer deposits but otherwise is at present of no economic importance. Little is known of its age except that it is pre-Tertiary, but its highly metamorphic character and general appearance suggests its possible correlation with the early Paleozoic or older Birch Creek schist of the Tanana basin.

In the lower basin of Talkeetna River there are areas of fine-grained schist, slate, and other metamorphic rocks which have been little studied and the relations of which have not been determined. They are here tentatively classified as Paleozoic or older.

Within the great bend of upper Susitna River there is a complex assemblage of rocks including greenstone, schist, limestone, slate, quartzose rocks, and dioritic and diabasic intrusives. The age of this assemblage is not accurately known, but it has been tentatively assigned to the Paleozoic, with a suggestion that it is Carboniferous or older. So far as known these rocks have no economic importance.

MESOZOIC SEDIMENTS.

Mesozoic sediments and fragmental volcanic materials are widely distributed in the Talkeetna Mountains, especially along their south and southeast border in the headward basin of Talkeetna River and in their northward extension beyond Talkeetna River. They are especially well known in Matanuska Valley and vicinity, where they have been studied with some care and have yielded sufficient fossils to make their identification certain. As described by Martin and Katz[1] they include Lower Jurassic volcanic breccia, agglomerate,

[1] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, 1912.

and tuff that are extensively developed on the north side of Matanuska Valley and in the headward part of the Talkeetna River basin. These fragmental materials, with some interbedded lavas, are waterlaid and well bedded and carry abundant marine fossils. In general they are of rather simple structure and have not been greatly deformed.

Lower Cretaceous rocks are known in this province at only a few localities, where relatively small areas of limestone occur. This limestone carries no fossils, but it lies unconformably upon Lower Jurassic volcanic rock and is provisionally correlated with the Lower Cretaceous. Sedimentary beds of Upper Cretaceous age cover a considerable area in the lower Matanuska Valley. They consist of shale and sandstone with a little conglomerate, have an aggregate thickness of at least 4,000 feet, and have been considerably faulted, folded, and deformed. The marine fossils found in these beds show clearly their Upper Cretaceous age.

On both sides of Susitna River, above its junction with Talkeetna and Chulitna rivers, and in many other areas in the northward extension of the Talkeetna Mountains there occurs an important group of sediments, mainly argillite and graywacke with minor amounts of limestone, that are almost devoid of fossils and that have on that account been difficult to correlate. Chapin[2] noted them on Tsisi Creek and suggested a correlation with the Upper Triassic rocks of the Valdez Creek district. Similar rocks occur east of Chulitna River, where they lie along the strike and seem to be a continuation of the slate and argillite of the Alaska Range, which have now been definitely shown to be, in part at least, of upper Mesozoic age.[3] From their lithology and structure these sediments are here mapped as of Mesozoic age.

MESOZOIC IGNEOUS ROCKS.

In the Mesozoic bedded rocks as described above has been included a series of volcanic breccia, agglomerate, and tuff, with some lava flows, all of which are of igneous origin, but having been laid down in sea water they are bedded and so may be described with the other sedimentary deposits. On the accompanying geologic map (Pl. I) the Mesozoic and Tertiary effusive and fragmental materials have for simplicity been grouped together and mapped with a single pattern. But far surpassing the sediments of the Talkeetna Mountains, both in area and in bulk, are the great masses of igneous rocks. These igneous materials fall into two classes—the acidic, coarsely

[2] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 27–28, 1912.

[3] Mertie, J. B., jr., Platinum-bearing gold placers of the Kahiltna Valley: U. S. Geol. Survey Bull. 692, pp. 236–237, 1919.

granular granitic rocks, all of which were intruded and cooled at considerable depths below the surface, to be later exposed by erosion, and the basic rocks, commonly termed greenstones, which were mainly poured out upon the surface as lava flows. Of these two groups the granitic rocks greatly preponderate in this province. The main mass of the Talkeetna Mountains, outlined by Chickaloon, Matanuska, Susitna, and Talkeetna rivers, consists primarily of a single great batholith of diorite, and throughout the northern extension of the mountains there are many smaller intrusive masses of the same type, satellites of the central mass.

The age of these granitic rocks is difficult to determine, and it is entirely possible that intrusions of similar materials have taken place at different times. It has been definitely established that the main Talkeetna diorite intrusion took place in mid-Mesozoic time, probably early in the Middle Jurassic. Some evidence is at hand to indicate that some of the outlying granitic masses are of Tertiary age, but in the lack of conclusive proof on this point and for the sake of simplifying the geologic map (Pl. I) all the granitic rocks are here mapped with a single pattern and indicated as mainly of Mesozoic age. The granitic rocks of this province are important because in some places, the most conspicuous of which is the Willow Creek district, they contain valuable gold-bearing quartz lodes, and elsewhere they show some copper mineralization.

In addition to the Mesozoic granitic rocks, there are considerable areas of basic igneous materials that are cut by the granitic intrusives and are therefore older. Those in the western Talkeetna Mountains have been described [4] as being characteristically andesite greenstone flows with amygdules of epidote, though some coarse-grained intrusive phases are present. Farther northeast, in the region of the great bend of Susitna River, Chapin [5] observed similar basalt and andesite, with associated tuff and breccia, that he tentatively assigned to the Triassic. It is likely that these rocks are of the same age as the similar materials in the western Talkeetna Mountains. Their chief economic importance lies in the fact that in places, notably on Iron Creek, they contain copper minerals in encouraging amounts.

TERTIARY SEDIMENTS.

Sedimentary rocks of Tertiary age are present in the Talkeetna Mountain province in only small tracts (Pl. I), but their economic importance is out of all proportion to their area, for they contain the coal of the Matanuska and Susitna basins. The actual distribu-

[4] Capps, S. R., Mineral resources of the western Talkeetna Mountains: U. S. Geol. Survey Bull. 692, pp. 195–196, 1919.

[5] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 26–27, 1918.

tion of these beds is no doubt much greater than the map indicates, for there is reason to believe that they have a considerable extent beneath the unconsolidated Quaternary deposits of the Susitna basin. Unlike the Mesozoic beds of this province, the Tertiary deposits are not marine but are believed to have been laid down in valleys or estuaries. They commonly contain the remains of land plants, but no marine shells.

The basal Tertiary beds in this province are composed mainly of arkose, with some conglomerate, shale, and sandstone, derived by weathering and erosion from the granitic mass of the Talkeetna Mountains. In Matanuska Valley these beds lap up against and overlie the edges of the granitic rocks and may even have extended over large areas from which they have now been removed by erosion. The lower Tertiary beds are folded and faulted and are intruded by igneous dikes and sills, especially in Matanuska and Little Susitna valleys, where they are best exposed. This group of beds lies beneath the coal-bearing portion of the Tertiary. The coal-bearing Tertiary beds of the Talkeetna region have been most carefully studied in Matanuska Valley, where coal mining has been carried on for a number of years. There the coal-bearing group of beds has been called the Chickaloon formation by Martin and Katz,[6] who describe it as consisting of a monotonous succession of shale and sandstone, in which gray to drab, rather soft and poorly bedded shale predominates. The sandstone is yellowish, rather soft, and for the most part feldspathic. The formation appears to be at least 2,000 feet thick and contains numerous coal beds. The beds have been generally tilted and locally folded. Faults are common, and the formation is cut by many dikes and sills, some of considerable size. The fossil plants it contains show that this formation is certainly Tertiary and probably Eocene. The coal resources are discussed in another place in this report.

At many other places around the western margin of the Talkeetna Mountains, in Susitna and Chulitna valleys, there are small exposures of Tertiary rocks, many of which contain lignite beds. These exposures usually occur in stream bluffs where the surficial deposits of later materials have been cut through, and they indicate a much wider distribution of coal-bearing beds than is shown on the map (Pl. I). The coal is without exception lignite, of poorer grade than the best Matanuska coals but comparable with the coal from the Nenana field. It has no value for export, as it is too poor in quality for bunker fuel and deteriorates on handling and exposure, but it has found some local use and will prove useful as a local fuel supply.

---

[6] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 42–52, 1912.

These scattered Tertiary beds have yielded no fossils, and their exact age is not known. It is possible, however, that the coal-bearing strata may ultimately be correlated with the Chickaloon formation.

Included in the areas mapped as Tertiary (Pl. I) there are certain large areas of massive conglomerate in the headwaters of Billy Creek and Oshetna and Nelchina rivers, which are doubtless Tertiary but whose exact age is not known. The Tertiary as mapped likewise includes the heavy Eska conglomerate of Matanuska Valley, which lies upon the Chickaloon formation and is overlain by Tertiary lava and tuff and therefore belongs within the Tertiary somewhere above the Chickaloon formation.

TERTIARY IGNEOUS ROCKS.

In the Talkeetna Mountain region igneous activity took place at intervals throughout Tertiary time. The igneous rocks range in kind from intrusive to extrusive and fragmental volcanic materials of basic and acidic character, and in age from the earliest Tertiary here represented to the latest. For the sake of simplicity the Mesozoic and Tertiary lavas and fragmental volcanic materials are here shown on the geologic map (Pl. I) as a single pattern.

The earliest Tertiary volcanic rocks that have been recognized in this region comprise certain basaltic lava flows that are interbedded with the basal Tertiary arkose in the Willow Creek district and therefore are probably of Eocene age. In the central Talkeetna Mountains, extending from Castle Mountain northwestward into upper Talkeetna Valley, there are extensive basaltic lava flows with intercalated pyroclastic rocks that cap the higher mountains of the region and are believed to be younger than the Eska conglomerate and may be as young as Miocene. Certainly these younger lava beds are much less deformed than the early Tertiary sediments. The Tertiary intrusive rocks of the Talkeetna province include a large number of irregular-shaped dikes and sills in the Matanuska Valley that are too small to be shown on Plate I. They are believed to be of late Tertiary age. In the northern extension of these mountains north of Susitna River there are considerable areas of intrusive rocks, including granite, quartz, monzonite, and granite porphyry, that are thought to be of Tertiary age. On the geologic map these rocks are grouped with the Mesozoic intrusives.

UNCONSOLIDATED SURFACE DEPOSITS.

In the Talkeetna Mountain province unconsolidated surface deposits in areas of noteworthy size are confined to the Susitna lowland, to the intermountain areas along the westward margin of the Copper-Susitna basin, and to narrow strips along the valleys of the

larger streams. On a map of the scale of Plate I only the larger areas can be shown. These deposits overlie unconformably all the older rock formations and in general are present only as a surface mantle of no very great thickness, though thick enough to conceal the underlying harder rocks. In the central part of the Susitna basin they may in places reach a thickness of a few hundred feet, and in the Copper-Susitna basin Quaternary materials are present in large volume, being exposed along the main stream valleys in bluffs several hundred feet high. The oldest of the unconsolidated Quaternary materials are of glacial origin—either directly, having been deposited as moraines by the great glaciers that then overrode this region, or indirectly, having been deposited as silt, sand, and gravel by glacier-fed streams flowing from the ice fields into the bordering lowlands. Materials laid down in this way form the bulk of the Quaternary deposits. After the recession of the last great glaciers the streams began once more the task of establishing courses with adjusted gradients over the surface bared by the receding ice. In places they cut sharp canyons through the valley filling, or even into hard rock. Elsewhere temporary lakes were formed, to be later filled. The mountain streams, many of which still head in active glaciers, supplied large volumes of rock débris which was carried into the lowlands and spread out as great gravel plains.

Erosion and deposition are still very active in this province, and the adjustment of the streams to their loads and gradients is still far from complete. Broad gravel and sand plains with spreading, branching stream channels alternate with narrow, steep-walled gorges, falls, and rapids. Great quantities of material are yearly carried to the sea to increase the area of the Susitna delta and fill up the Cook Inlet embayment.

The lowland areas that are floored with Quaternary unconsolidated materials constitute the land upon which the future of agriculture in Alaska depends. The Cook Inlet-Susitna lowland has great areas that without doubt will some day support a large farming population. Already a considerable number of homesteads have been taken up in Matanuska Valley and around Knik Arm, and these pioneers have shown that a living can be won from the soil. The lowland surrounding Cook Inlet and in the lower Susitna Valley is one of the most promising areas in Alaska for agriculture, and its development, now barely begun, will be greatly stimulated by the advantages of rail and water transportation.

The lowlands on the western margin of the Copper-Susitna basin, though probably possessing fertile soils, are much less favorable for farming, for their altitude, about 3,000 feet above sea level, gives a much shorter growing season. Frosts may occur there during

almost any month. They have large possibilities, however, as grazing lands.

ALASKA RANGE.

The portion of the Alaska Range here considered lies at the elbow or hinge where the trend of the mountains changes from a west-northwesterly direction east of Broad Pass to a southwesterly direction west of Susitna and Chulitna valleys. This range, which was elevated to about its present height in late Tertiary time, represents an ancient line of weakness in the rocks and has been the site of folding, close deformation, and mountain building repeatedly during the geologic history of the continent. The present range, which is conspicuous as one of the great physiographic features of North America and contains our highest mountain, is relatively young but is already in process of being torn down and leveled off by rivers and glaciers. The weakness of the rocks, however, will persist, and as in the past the range may be rebuilt again and again.

PALEOZOIC AND OLDER ROCKS.

Undifferentiated metamorphic rocks.—The recurrence of mountain-building processes in this range is shown by the varying degrees of alteration and deformation in the rocks that compose it, the oldest showing evidence of greatest and most numerous periods of stress and the youngest much less metamorphism and compression. The most ancient rocks in the range consist of mica schist, now closely folded, contorted, and recrystallized to such a degree that the character of the sedimentary beds from which it originated can scarcely be recognized.

These rocks, called the Birch Creek schist, form an important element of the northern flank of the mountains. They contain no fossils, any organic remains which they may once have carried having long ago been destroyed. Their age is not accurately known, but they are very ancient, probably pre-Cambrian. Similar rocks occur in the Willow Creek district of the Talkeetna Mountains, already described, and are widespread in the Yukon-Tanana upland, north of Tanana River. Their economic importance arises from the fact that in many places they contain gold-bearing quartz veins, and by the erosion of these veins and the concentration of the contained gold in the stream placers many rich deposits have been formed, including the highly productive placers of the Fairbanks district.

North of the belt of Birch Creek schist and forming the northern range of foothills of the Alaska Range is a parallel belt of undifferentiated metamorphic rocks that were originally mainly of igne-

ous origin but contain also considerable sedimentary material. These rocks have been grouped as an undifferentiated complex of metamorphic materials and called the Totatlanika schist.[7] One characteristic phase is an augen gneiss, with quartz and feldspar crystals in a groundmass of fine-grained quartz and mica. With it are associated sericite schist and materials of sedimentary origin, including black slate, carbonaceous slate schist, limestone, and quartz conglomerate, so closely infolded and involved with the quartz-feldspar schist that they have not been differentiated. The age of this series of schist and gneiss is not accurately known, but its sedimentary phases have been correlated with the Tonzona rocks, tentatively considered as of Devonian or Silurian age. On the accompanying geologic map (Pl. I) the Birch Creek schist and the Totatlanika schist have been grouped together, as falling within the category of undifferentiated metamorphic rocks of Paleozoic age or older. The Totatlanika schist contains a few mineralized veins, some of which carry gold in encouraging amounts, associated with arsenopyrite, bismuth minerals, stibnite, and chalcopyrite. These veins in general are associated with the carbonaceous slate schist, are near small acidic intrusive bodies, and are related to faulting.[8]

Undifferentiated Paleozoic sediments.—In the part of the Alaska Range that lies west of the railroad, in the Broad Pass region, there are considerable areas of sedimentary rocks which are pretty definitely known to be Paleozoic but whose age has not yet been accurately determined. Thus, on the north flank of the main range and between Sanctuary and Nenana rivers there is a considerable area in which the prevailing rocks are black shale and slate that have been completely folded, faulted, and contorted, although less severely altered than most of the beds of the Tatina and Tonzona groups, described below. These beds underlie the Cantwell formation unconformably, and conceivably they may be Mesozoic, but their general character and relations point somewhat more strongly to a Paleozoic age, and they are here grouped with the Paleozoic sediments.

On the west side of Chulitna Valley, between Ohio Creek and Bull River, there is a belt of metamorphic rocks, mainly greenstone tuff and agglomerate but with associated chert and slate, that form the surface upon which the Triassic materials were unconformably laid down. Their age is not known except that they are pre-Triassic, and in the lack of more definite information they are here classed with the undifferentiated Paleozoic sediments.

---

[7] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 34–37, 1919.

[8] Overbeck, R. M., Lode deposits near the Nenana coal field: U. S. Geol. Survey Bull. 662, pp. 351–362, 1918.

Paleozoic sediments.—Within the portion of the Alaska Rang here under discussion there are various areas of sedimentary rock all more or less metamorphosed, which have been determined wit some degree of certainty to be of Paleozoic age. One such are composed of beds of the Tatina group,[9] is a prominent element in th north flank of the Alaska Range west and north of Mount McKin ley and is continued eastward as a narrow strip in the headwater of Kantishna River. The Tatina group includes a thick series o limestone, black slate and argillite, chert, shale, and sandstone, al intensely folded, crumpled, and deformed. In this area these rock have yielded no fossils, but they unconformably overlie the much olde Birch Creek schist and are succeeded by the much younger Cant well formation. Brooks has traced these rocks continuously south westward beyond the area here considered into the upper Kuskokwin basin, where he found Ordovician fossils in the base of this group The lower part of the group is therefore definitely of Ordovicia age, but the unfossiliferous upper part may be as young as th Silurian.

A short distance north of the Tatina rocks, in the upper basin o Kantishna and Sanctuary rivers, is a narrow belt of sediments, lyin parallel to the axis of the range, that consists of black argillite, slate and phyllite, with some schist, graywacke, and chert, all much folded faulted, and crumpled. These rocks, which have been called th Tonzona group, are to be distinguished from the Tatina rocks prin cipally by the absence of limestone, although they are themselve more or less calcareous and are in places cut by multitudes of smal calcite and quartz veinlets. They are considered by Brooks [10] to be o Silurian or Lower Devonian age. These Tonzona sediments ar believed to be the equivalent of the sedimentary basal phase of th Totatlanika schist, already described with the undifferentiated Paleo zoic rocks. In the Bonnifield region the Totatlanika schist, as de scribed by Capps,[11] includes metamorphic rocks of both sedimentar and igneous origin, and the sedimentary phase is believed to cor respond to the Tonzona beds as studied by Brooks farther west, wher the igneous material was less abundant.

At the junction of Nenana and Cantwell rivers the railroad rout crosses a belt of sediments, including massive limestone, black slate graywacke, and chert, and some associated diorite intrusives. These rocks occupy the highest part of the range between the heads o Toklat and Cantwell rivers and are continued eastward into the

---

[9] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 69–73, 1911.

[10] Idem, p. 76.

[11] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 687, pp. 34–37, 1919.

upper Nenana basin by smaller, isolated masses. The most conspicuous member of this group is a massive white limestone, locally crystalline. All the sediments have been more or less metamorphosed, particularly in the vicinity of the diorite. The limestone itself has in several places yielded fossils of Middle Devonian age. The associated sediments have yielded no fossils, and all that can be said concerning any particular bed in this group is that it lies below or above the limestone and is therefore older or younger than the limestone. It seems safe to say, however, that most of these rocks are of Devonian age.

MESOZOIC AND EARLY TERTIARY (?) SEDIMENTS.

In that part of the Alaska Range here considered sedimentary rocks of Mesozoic or early Tertiary age constitute the largest single element, at least in point of area (Pl. I). These sediments may be divided into two major subdivisions—one of marine origin consisting primarily of shale, slate, and graywacke, with some limestone, and ranging in age from Triassic to Cretaceous, and the other a continental deposit, composed dominantly of conglomerate, sandstone, and shale, of late Mesozoic or earliest Tertiary age. The marine shale, slate, and graywacke are largely confined to the Susitna slope of the range.

Triassic rocks have been identified at two distinct localities in this province—one near Butte Creek,[12] in the Valdez Creek district, where the rocks consist prevailingly of dark-blue and black slate with interstratified beds of arkose and graywacke, and the other on the West Fork of Chulitna River,[13] where they include a series of limestone, tuff, and shale, with associated lava flows, in which are found mineralized areas containing copper and gold bearing lodes. These beds lie unconformably upon a group of tuffs and metamorphic sediments, supposedly of Paleozoic age, and represent the oldest known Mesozoic rocks of this region. In the valley of West Fork of Chulitna River there is a thick series of black argillite and slate, together with some graywacke and fine conglomerate, that extends across the strike for a distance of more than 7 miles, with prevailing steep dips to northwest. These beds seem to lie stratigraphically above the Triassic rocks and certainly are beneath the Cantwell formation, described below. They are therefore probably of Mesozoic age and may belong to either the Jurassic or the Cretaceous, or in part to each. This conclusion is confirmed by the strike of the beds, which would

[12] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pp. 29–31, 1915.

[13] Capps, S. R., Mineral resources of the upper Chulitna region: U. S. Geol. Survey Bull. 692, pp. 216–217, 1919.

carry their extension southwest to the Yentna district, where Mertie[14] has found fossils, determined as probably of Upper Cretaceous age, in a similar series of slate and graywacke. It is thus pretty definitely proved that the great sedimentary series that forms the southeast flank of the Alaska Range in the Susitna and Chulitna basins is mainly of Mesozoic age.

The second great subdivision of this Mesozoic-Tertiary belt, the continental phase, embodies the Cantwell formation, a thick series of conglomerate, sandstone, and shale that forms a major element in the range from Muldrow Glacier eastward to and beyond the east margin of the region here under consideration. These rocks are hard and resistant to weathering, form rugged mountains, and with the brightly colored lavas and intrusive rocks with which they are associated yield the striking scenery to be found in the upper Toklat basin. In general they are much less metamorphosed than any of the older formations, though locally they have been intensely crumpled and broken and even reduced to stretched conglomerate and schist. East of Nenana River the Cantwell beds have been extensively intruded by granitic rocks.

The age of the Cantwell formation is still open to discussion, for although fossil leaves, said to be of Eocene age, have been collected from it in several places, there seem to be certain conflicts between the evidence furnished by the fossil plants and that supplied by stratigraphy. There is no disagreement among the geologists who have studied this problem in regard to the conclusion that the Cantwell formation is younger than the Mesozoic shale, slate, and graywacke that are so abundant on the southeast slope of the range. Furthermore, the Cantwell beds appear much older, when judged on the basis of induration and metamorphism, than the next younger deposits, the Tertiary coal-bearing beds, and probably lie unconformably beneath them. Yet these loosely consolidated and only moderately deformed coal-bearing beds closely resemble and are generally correlated with the coal-bearing beds of the Matanuska field, which are assigned to the Eocene epoch—the same age assignment that has been made for the Cantwell. It is therefore suggested that if the coal formation in the Nenana basin is basal Eocene, then the Cantwell must be as old as Upper Cretaceous. If the Cantwell is Eocene, then the near-by coal formation must be later Tertiary than the Eocene. For the purposes of the present description the Mesozoic formations and the Cantwell formation have been mapped with a single pattern on the accompanying geologic map (Pl. I).

[14] Mertie, J. B., jr., Platinum-bearing gold placers of the Kahiltna Valley: U. S. Geol. Survey Bull. 692, pp. 236–237, 1919.

TERTIARY COAL-BEARING FORMATION.

The Tertiary coal-bearing formation, though present in the Alaska Range only as small, irregular patches which even in the aggregate have no great area, is economically of great importance, for in most of the areas shown on Plate I it contains workable beds of lignite that together form a fuel reserve probably running into the billions of tons. From the character and habit of these beds they occur generally in the lowlands, where vegetation and younger stream and glacial deposits commonly mask the underlying rocks, and the outcrops are commonly found only in recent stream cuts of small area. The actual extent of the deposits is therefore considerably greater than is shown on the accompanying geologic map, where the formation appears only as small scattered dots and patches, except in the Nenana coal field, where the coal-bearing formation occupies a larger surface area.

The Tertiary coal-bearing formation consists mainly of unconsolidated or little consolidated clay, sand, and fine gravel, usually of rather light color, and at nearly every place where it is well exposed it shows the presence of lignitic coal. One unusually complete section measured on Healy Creek[15] shows 23 distinct coal beds ranging from 1 to 40 feet in thickness, with an aggregate thickness of lignite of over 230 feet. Other sections on Healy and Hoseanna creeks show from 10 to 15 lignite beds aggregating 60 to 130 feet in thickness. The lignite is of good grade, being similar in quality to that mined on lower Cook Inlet. It is now sometimes classified as subbituminous. It is known to occur at intervals from the head of Moose Creek, in the Kantishna district, eastward to and beyond the region here treated. The most completely exposed sections of this formation occur in the Nenana coal field, near the railroad, and this field contains so much easily accessible coal that it is unlikely that the smaller outlying areas will be exploited for a long time to come, except for local use.

The coal-bearing beds of the Alaska Range are certainly of Tertiary age, but they have not yet been finally assigned to any particular part of the Tertiary. Their only fossils are plant remains, which though abundant are usually not well preserved and occur in incoherent sediments too weak to stand collecting and shipment. Those that have been examined indicate a lower Eocene age. To the geologist familiar with the coal-bearing formation of Cook Inlet and the Susitna basin, the resemblance of the beds in the Nenana field to those there is so striking that he has little hesitation in correlating the two formations. The coal formation of the

[15] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, fig. 3, 1912.

Susitna basin has yielded fossils that have been definitely identified as Eocene. Yet in the Alaska Range the Cantwell formation, which to judge by its lithology and degree of deformation is much older than the coal-bearing rocks, is also classified as Eocene, on the basis of its fossil plants. Therefore, if the age of the Cantwell formation is accepted as Eocene, it is necessary to conclude that the coal formation of the Nenana field is younger than Eocene and therefore younger than the coal formation of the Susitna basin and not to be correlated with it. Further facts will be necessary before this problem can be finally solved.

UNCONSOLIDATED SURFACE DEPOSITS.

The Alaska Range is largely bordered by areas of unconsolidated surface deposits. On the north the broad Tanana lowland, floored with alluvial deposits of gravel, sand, and silt, stretches northward to Tanana River, and on the south and east are other great basin areas in which glacial and stream deposits form a mantle over the underlying rocks. Within the range itself, too, there are large areas, including the valley floors of the larger rivers and the basins between the foothills and the main range, in which loose materials, mainly gravel, are present in considerable amount. On the accompanying geologic map (Pl. I) only the larger of such areas could be shown.

The unconsolidated surface deposits, as that phrase is here used, include materials of great range in age, as well as in character and mode of origin. The oldest beds included in this group are those of the Nenana gravel,[16] which occurs over an extensive area on the north flank of the Alaska Range and is well exposed along the line of the railroad between Healy and Moose creeks, where it may be seen in the high bluffs on the east side of Nenana River, with the coal-bearing formation in places showing beneath it. This gravel consists of fine to coarse unconsolidated stream deposits, rather poorly stratified, that were laid down as a great outwash apron along the north front of the range after the first great Tertiary mountain uplift. The deposits are deeply oxidized, in places show considerable folding, faulting, and tilting, and have been deeply eroded by many of the northward-flowing streams that cross them. On the mountain just north of the mouth of Hoseanna Creek gravel of this formation is to be found at an altitude of nearly 3,000 feet above the adjacent valley of Nenana River. Gold King Creek, farther east, has cut a wide valley 1800 feet deep into the gravel without exposing its base. On lower Healy Creek 1,760 feet of gravel is exposed, and the top of the formation is lacking.

[16] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pp. 30–34, 1912.

The variations in the structural relations of the Nenana gravel from place to place indicate that the conditions of its deposition and later history were not everywhere the same. Thus in the Nenana coal field Martin found that the Nenana gravel is generally unconformable upon the coal-bearing Tertiary beds. In other parts of the region there is no recognizable unconformity between the two. The presence of an unconformity at the base of the gravel in some places shows positively that at those places the coal-bearing beds were somewhat uplifted and warped and then eroded before the overlying gravel was laid down. For the north flank of the Alaska Range as a whole, however, it may be said that the Nenana gravel has been uplifted, folded, tilted, and faulted to about the same degree as the underlying coal-bearing Tertiary beds, and most of the mountain-building movements that affected the coal-bearing formation affected the gravel also. This justifies the statement that if the main uplift of the Alaska Range took place before Quaternary time, then the Nenana gravel is Tertiary. On the other hand, the Nenana gravel carries on its surface, in places, great boulders and blocks that show striae and are apparently of glacial origin, and glaciated pebbles have been found that may have come from the gravel itself. If the Nenana gravel contains glacial pebbles, that indicates its Quaternary age. These apparently contradictory facts may be due to a different conception by various observers as to what deposits should be included in the Nenana formation.

Within the Alaska Range itself glaciation in Quaternary time was widespread, and the former more extensive glaciers left in many places moraines or till deposits. South of the range the glaciers reached tremendous size, entirely filled the intermountain areas, and sent tongues down Susitna and Copper rivers to the sea. Over that entire area glacial deposits form a large part of the unconsolidated surface materials. On the north flank of the Alaska Range, by contrast, the glaciers during Quaternary time were almost entirely confined to the mountains or at most protruded only short distances down the larger stream valleys into the bordering lowland. As a consequence, glacial deposits are much less abundant on the north slope of the range than on its south slope, and those on the north are to be found mainly in the larger stream valleys. In the higher mountains each valley head still contains a glacier, and ice streams of notable size radiate from the lofty group of peaks around Mount McKinley and from the high ridges near Cathedral Mountain, Mount Hess, and Mount Hayes. Each of the glaciers is engaged in gnawing its bed into the heart of the mountains, and the rock débris is deposited as moraines or delivered to the torrential streams to be laid down in the lowlands as fluviatile gravel. The deposition of glacial fluviatile gravel, though still actively in process, is now tak-

ing place on a much smaller scale than during the time of great ice expansion. The Tanana lowland north of the range is floored with a great sheet of these materials, and the aggradation of this lowland with stream-brought débris of glacial origin is still going on, though at a slower rate than in the past.

Stream gravel is present also along valleys that no longer contain glaciers and in places that have never been glaciated. In such places the valley deposits have not even a remote glacial orgin, but generally in this region the stream deposits are of complex derivation, part being the outwash from glaciers and part the result of normal stream erosion and deposition.

IGNEOUS ROCKS.

Igneous rocks occur in all the formations of the Alaska Range from the ancient Birch Creek schist to the Tertiary coal-bearing rocks. They include old Paleozoic and possibly pre-Paleozoic intrusives and flows that have been altered along with the sediments, to form the mica schist and gneiss; Mesozoic granite, intrusive and extrusive greenstone, and greenstone tuff; and late Mesozoic or early Tertiary rhyolite, andesite, and diabase, along with dikes and sills of the same age. Nevertheless, in spite of the many periods of igneous activity which this region has experienced and the great variety in the character of the igneous material, the portion of the Alaska Range shown on Plate I is composed mainly of sedimentary rocks, and the areas of igneous rocks it includes are of relatively small extent.

YUKON-TANANA UPLAND.

The northern edge of the region here described lies on the south margin of the Yukon-Tanana upland, a broad province roughly bounded by Yukon and Tanana rivers and the Alaska-Canada boundary. This upland consists of flat or slightly rounded, even-topped ridges reaching altitudes of 2,000 to 3,000 feet above sea level, separated by comparatively narrow, closely spaced valleys. This province has had a very different geologic history from the mountainous provinces farther south. The mountains owe their present altitude to the deformation of the rocks, which have been compressed into great folds, to be later carved by the agencies of erosion, as in the Chugach, Kenai, and Alaska ranges, or to the injection beneath the surface of great masses of igneous rock, with accompanying folding and faulting around the margins of the intrusion, as in the Talkeetna Mountains. The present relief of the Yukon-Tanana upland is to be explained in a different way. In the geologic past that region has been closely folded at successive periods, but ap-

parently most of the folding ceased sometime in the Tertiary period and was followed by a long interval of time during which the agencies of erosion were active on this land mass, reducing it to a region of low relief. Later this area was uplifted bodily, without general folding, and the present surface forms are the result of stream erosion upon this uplifted land mass, the smooth ridge tops representing portions of the old land surface.

PALEOZOIC OR OLDER METAMORPHIC ROCKS.

The oldest rocks in the Yukon-Tanana upland and those of widest surface distribution belong to the assemblage known as the Birch Creek schist.[17] It includes quartzite schist alternating with quartz-mica schist; feldspathic, carbonaceous, and amphibole schists; and some crystalline limestone. These rocks are mainly of sedimentary origin and are similar in every way to the Birch Creek schist as described in the section on the geology of the Alaska Range. The structure of this formation is very complex, including close overturned folds and intricate crumpling, but the general strike is northeast. These schists are believed to be of pre-Ordovician age and may be in part as old as pre-Cambrian. Their areal distribution is shown on the accompanying geologic map (Pl. I). As will be shown later, their chief economic importance arises from the fact that they contain gold-quartz, antimony, and tungsten lodes, and from these erosion has produced rich gold placer deposits.

PALEOZOIC SEDIMENTS.

Within the region here considered the only rocks besides the Birch Creek schist that occupy large areas in the Yukon-Tanana upland are the beds of the Tonzona group, which have been described by Prindle[18] as comprising a series of red, green, and black argillite, conglomerate, and sandstone, with some chert and limestone. These rocks are all considerably metamorphosed and have yielded no fossils in the type areas, and their exact age is not known. They are believed to lie unconformably upon the older formations and are tentatively assigned to the Devonian. They are in many places cut by numerous veins and stringers of quartz, some of which are known to contain gold, and the erosion of these mineralized veins and the concentration of their heavy metallic content in the stream beds has led to the formation of valuable gold deposits in the Hot Springs district.

---

[17] Prindle, L. M., The Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, pp. 35–36, 1913.

[18] Idem, pp. 44–45.

MESOZOIC AND TERTIARY SEDIMENTS.

Sedimentary rocks of Mesozoic and Tertiary age have been recognized at many places in the Yukon-Tanana region, but in that part of the region here described they are generally lacking.[18a]

IGNEOUS ROCKS.

Although the older schists of this region are mainly of sedimentary origin, they contain also some igneous materials that have been metamorphosed along with the inclosing sediments and like them have been reduced to schist. In addition to these altered igneous materials there are in the Yukon-Tanana upland many scattered areas of granitic intrusive rocks, some of which fall within the region shown on Plate I but most of which are too small to be shown on a map of this scale. For the most part these intrusions consist of granite, monzonite, or diorite, related coarse-grained rocks that were injected into the overlying rocks and cooled at depth. These intrusive rocks are thought to be mainly of late Mesozoic age. Elsewhere such intrusive masses are believed to have caused the mineralization of the surrounding country, for gold-bearing quartz veins are present near the margins of many such masses. The quartz veins in this region may be genetically related to the granite intrusives.

UNCONSOLIDATED SURFACE DEPOSITS.

The part of the Yukon-Tanana upland shown on the accompanying map (Pl. I) borders the north edge of the Tanana lowland, which is a region heavily mantled by unconsolidated surface deposits, including stream gravel, silt, and muck.[19] Glacial materials are lacking in this area, for the northward-flowing ice tongues of the Alaska Range never reach so far, and the Yukon-Tanana upland supported glaciers at only a few places. A fuller account of Quaternary events in the region north of Tanana River is given in the following pages.

PLEISTOCENE AND RECENT GEOLOGY.

In the discussions of the geology of the several mountain provinces of this region some description has been given of the unconsolidated deposits in each of them. By early Quaternary time the great mountain-building movements in this part of Alaska had been largely completed, and the greater topographic features, including the Chu-

---

[18a] In the extreme northwestern part of the region there are some rather large areas of highly folded argillite, slate, and quartzite that are now considered Lower Cretaceous, although they were considered Paleozoic when this report was written. This information came to hand too late to be incorporated in the accompanying geologic map.

[19] "Muck" is a miner's term for the prevailing thick layer of peaty and organic material that commonly overlies the gravel in the deep placer mines.

gach-Kenai Mountains, the Talkeetna Mountains, the Alaska Range, and the Yukon-Tanana upland, had been elevated to approximately their present altitudes and were surrounded, as now, by great lowland basins. These land areas at that time must have had a very different appearance from that we now see, however, for the agencies of erosion then active in sculpturing the land forms were those of a temperate climate, and glaciers, if present at all, existed only in the valley heads of the highest mountains and had as yet produced no effect upon the country as a whole. The Yukon-Tanana upland is an exception to the above general statement, for in early Quaternary time its appearance may have been much as it is now, except that the deep valley filling now present in so many stream basins did not then exist, and the relief was greater by an amount equal to the depth of that fill. Then, as now, the streams throughout this region had their sources in the mountains, flowed by steep gradients to the lowlands, and there gathered into great rivers that followed Tanana and Susitna valleys to the sea. The details of the drainage lines may have been very different, in large and small features, from those of the streams as shown on our present maps. The upper basin of Copper River probably discharged its waters into what is now the upper Susitna or Chulitna valley. Tanana River, instead of joining the Yukon, probably flowed southwestward into the upper Kuskokwim. Cook Inlet may have reached northward a much shorter distance than at present, and the south and east coast of Kenai Peninsula and the shores of Prince William Sound were much more regular and were lacking in the deep fiords and numerous islands by which they are now characterized. But the general position of the mountain ranges and their relations to one another and to the lowlands were in the main like those of to-day.

GLACIAL EPOCH.

GROWTH OF GLACIERS.

The glacial epoch, occupying that portion of geologic time known as the Pleistocene, was brought about by a change of climate that probably involved both a decrease in the mean annual temperature of the region and an increase in precipitation. The snow line in the mountains crept down to lower and lower altitudes, such glaciers as already existed in the high mountains became larger, and other valley heads that had earlier been free from glaciers now received a filling of içe and snow that grew in size and thickness from year to year. Like most other events in earth history this change must have been gradual, comparatively warm years alternating with more frequent and increasingly cold years. Perhaps had there been people living in the region at the time, the change during any one man's life-

time might have been scarcely noticeable, yet in the course of centuries a great change came about. Each mountain range became the nourishing ground of a multitude of alpine glaciers, one of which formed in the head of each high valley. These grew slowly larger, lengthened downward, and joined in the trunk valleys, until the water streams were replaced by ice streams, differing from the ordinary rivers in that instead of flowing only along the valley floors, they filled their basins brim full. This process continued until a very large part of the region here considered was buried hundreds and even thousands of feet deep beneath a great mass of slowly moving ice. The direction of the ice movement was controlled, as is that of streams, by the shape of the surface over which it moved. In the mountains the ice currents generally followed the preexisting valleys, and a typical glacier consisted of a main ice lobe in a larger valley, nourished by many branching glaciers from the tributary valleys. In many places, however, where there were low passes or gaps in the valley walls, the brimming ice flowed through from one valley to the next, thus giving a much more complex drainage pattern than that of ordinary streams.

EXTENT OF GLACIATION.

As the mountain glaciers slowly grew larger and longer they pushed out beyond the mountain fronts into the lowlands. This was especially true of the glaciers on the Pacific slope, for on that slope the precipitation was heaviest and the growth of the glaciers was therefore most rapid. The Copper-Susitna basin, completely surrounded by the lofty ridges of the Chugach and Alaska ranges and the Talkeetna and Wrangell mountains, was inundated by ice from a multitude of vigorous tributary glaciers until it was filled to overflowing. This great Copper River glacier found many outlets through which to discharge its ice and its waters. A part of its drainage escaped southward through the narrow gorge of Copper River at Woods Canyon, a gorge which is of glacial and postglacial origin and which has been the outlet for the drainage of this great basin only since glacial time. Some of the ice and water of this glacier escaped northeastward into upper Nabesna Valley and northward through Suslota, Mentasta, and Delta passes to the Tanana, but a larger part of the ice probably moved westward into the Susitna basin by way of Matanuska Valley and across the lowland to the present valley of upper Susitna River. The Copper River glacier thus formed a continuous ice field with that in the Susitna basin.

The Susitna-Cook Inlet depression was likewise filled with ice at the time of the maximum glaciation. The much larger ancestors of the present glaciers of the Alaska Range poured down their mighty ice streams to coalesce in the lowland with one another, with the over-

flow ice from the Copper River glacier, and with the glaciers reaching down from the Talkeetna, Chugach, and Kenai mountains. The Susitna glacier filled its basin with ice to a great depth, overflowed northward across the range through Nenana Valley, and pushed southward well down the present Cook Inlet embayment. At their greatest the glaciers south of the Alaska Range were so large and thick that only the highest ridges of the great mountain masses projected above the surface of the ice. In the valleys of Chulitna and Susitna rivers the main ice lobe at one time stood to depths of 3,000 and 4,000 feet, with steeply sloping tributaries pouring down to it from all sides.

On the northern, inland slope of the Alaska Range the development of Pleistocene glaciers was much more moderate than on the south slope. This was due to several factors, chief of which was the lesser precipitation. The asymmetric position of the axis of the range, which is much closer to the north flank of the mountains than to the south flank, also played a part, as it gave the northward-flowing glaciers a much smaller collecting ground. At any rate, the glaciers from the Alaska Range tributary to Tanana Valley, though reaching far beyond their present limits, at their maximum succeeded in pushing northward but a short distance beyond the mountain front and out into the lowland. So far as is now known, none of these ice streams stretched northward as far as the present course of Tanana River, and they failed to spread laterally in the lowland sufficiently to coalesce with one another.

The Yukon-Tanana upland, being a region of only moderate relief and of small precipitation, was at no time in the Pleistocene epoch extensively invaded by glacial ice. On a few of the highest peaks and domes small valley glaciers formed, but these never reached any great size.

In a few places in Alaska evidence has been found of at least two ice advances, one much older than the last. We know that elsewhere on the American continent there were several successive ice advances, separated by periods of deglaciation, and probably the same thing is true of Alaska also, but the available evidence on this point is meager, the last glaciers having to a great extent overridden the deposits of their predecessors and destroyed or confused the evidence. Along the course of the railroad in the Nenana Valley, however, the deposits of two distinct periods of glaciation can be seen. The terminus of the ice during its last pronounced advance lay in the vicinity of the junction of Healey and Dry creeks with Nenana River, and a terminal moraine may be seen on the west side of the river north of Dry Creek. Farther north, near the point where the railroad emerges from the foothills onto the lowland, there are near the railroad track a number of large granite boulders that

were brought from the mountains by an older and more extensive glacier. The northern limit reached by that glacier is not known, but it possibly extended some distance out upon the lowland.

EFFECT OF GLACIATION ON LAND FORMS.

The glaciers of this region have had profound effects on the shape of the land forms as we now see them, effects which in the highlands resulted mainly from the sculpturing by the vigorous, rock-studded ice streams of the sides and beds of their confining valleys, while in the lowlands and near their termini the glaciers modified the surface by depositing the great quantities of detritus torn from the headward portions of their beds. In all the higher mountains, where the glaciers had steep gradients and relatively rapid motion, the valleys are now broadly U-shaped in cross section, have wide floors with steeply rising walls, and are straight or bend only in broad, sweeping curves. They thus differ strikingly from normal stream-eroded valleys, which are V-shaped in cross section and follow a sinuous course between the spurs that descend to the valleys from both sides. Glacial valleys are also characterized by amphitheater-like heads, with steep surrounding cliffs, by hanging tributary valleys, by lakes, and by many other features that show plainly the powerful erosion to which a glacier subjects its bed.

In the lowlands the visible results of the former occupancy by glacial ice are of a different character. There the glaciers, having descended to altitudes at which the mean temperature was no longer low enough to favor the accumulation of ice, were gradually wasted by melting and so dropped their loads of débris picked up farther toward their heads. The débris was deposited as terminal moraine, of hummocky, irregular surface, or as ground moraine beneath the ice, or was fed to the torrential streams that flowed from the melting ice and deposited farther downstream as outwash materials. On the accompanying map the lowland areas are shown as occupied by unconsolidated surface deposits, and these deposits are, in large part at least, composed of materials that directly or indirectly are of glacial origin. In many places these unconsolidated deposits are very thick over large areas. The stream bluffs of Copper River, near Copper Center, and of many of its tributaries show glacial till, sand, silt, and gravel to a depth of more than 500 feet without revealing the underlying bedrock, and it is safe to say that throughout that basin, an area of some 3,000 square miles, the materials of glacial origin average over 100 feet in thickness. The northwest border of this extensive basin deposit lies in the east-central portion of the area here under discussion, and the glacial materials so thoroughly conceal the topography of the underlying bedrock that

it is still impossible to say just what course the preglacial drainage from the Copper River basin followed to join the Susitna, but doubtless that course is buried somewhere in the upper Susitna basin.

The size, shape, and depth of upper Cook Inlet and the surface forms throughout the Cook Inlet-Susitna lowland have been greatly modified by the deposition of débris from the glaciers. The discharge of glacial sand, gravel, and silt was doubtless much more active during the periods of great ice expansion than it is now, and glacial till and outwash materials were deposited in great quantity throughout this lowland, as may be seen from the wide distribution of such deposits, as shown on the accompanying map (Pl. I). These deposits have not generally been so deeply dissected by streams as those in the Copper River basin, and their thickness can only be inferred, but on the east shore of Cook Inlet, from Anchor Point to Point Possession, there are almost continuous bluffs, from 100 to 400 feet high, that show unconsolidated surface materials without generally revealing the underlying Tertiary rocks.

To-day, during a period of ice recession, the deposition of glacial outwash is still actively in progress at the mouths of Matanuska, Knik, and Susitna rivers and many other smaller streams. Their deltas are encroaching on the shallow waters of Cook Inlet, and great volumes of silt, carried back and forth by the tides, are being built up as extensive low-tide mud flats and shoals.

The Tanana lowland was never extensively invaded by glacial ice, but its surface has been greatly modified by glacial outwash brought down from the Alaska Range by the many glacial streams. By no means all the unconsolidated sand, gravel, and silt of that lowland, however, can be ascribed to glacial erosion and extraglacial deposition, for the filling of the lowland with detritus from the mountains began in preglacial time, perhaps about the middle of the Tertiary period, when the elevation of the Alaska Range first began. Since then deposition in the lowland has been continuous, though with greatly varying rapidity. No doubt the removal of material from the mountains and its transportation northward to the lowland by glaciers and the torrential glacial streams were tremendously stimulated at times of widespread glaciation, and some measure of that quickening may be gained by observing the heavy load of detritus now carried by the streams that head in the greatly shrunken glaciers that remain to-day.

Since mid-Tertiary time the Tanana lowland has been filled up to a depth of many hundred feet with unconsolidated deposits of gravel, sand, and silt, mainly derived from the Alaska Range. This filling has not only altered the whole appearance of the Tanana lowland but has had a far-reaching economic effect upon the gold placer de-

posits of the Fairbanks district. The Fairbanks gold placers, as well as those of the Tolovana district, are unusual in that in the headward, steep portions of the streams the gravel is shallow and the streams flow near the bedrock floors of their valleys, whereas in their lower courses the bedrock floor is deeply buried by gravel and muck, and the streams flow over a valley filling whose thickness reaches 100, 200, or even 300 feet. The cause for this deep burial of the bedrock floor and consequently of the placer gold, which usually occurs in gravel near the bedrock, is probably complex and may involve many factors, including warping, but certainly one cause that may be competent to explain most of the present conditions is the gradual deep filling of the Tanana lowland by débris from the range to the south. The building of alluvial fans northward into the Tanana lowland by such glacial streams as Kantishna, Nenana, Wood, Little Delta, and Delta rivers has crowded Tanana River northward out of the valley axis, so that it now flows in a sinuous course that follows closely the foot of the rock hills that border the basin on the north. The small, sluggish tributaries of the Tanana from the north, carrying little débris, were unable to throw out comparable fans, and as the valley filling from the south progressed their gradients were decreased, their lower courses became marshy, and vegetation accumulated to form the muck now generally present.

There is evidence in the Fairbanks district that in time past the valley filling was considerably deeper than it is now, but there still remains a filling in the lower valleys of Chatanika River and other tributaries of the Tolovana that is at least 200 to 300 feet thick, and this probably represents the minimum measure for the average thickness of unconsolidated materials in the Tanana lowland. At the valley axis these deposits may be very much thicker.

POSTGLACIAL EROSION.

Since the retreat of the last great glaciers aggradation has continued in many parts of the lowlands, but in the higher mountains glaciers and streams have continued to erode their beds and to modify the surface uncovered by the retreating ice sheets. In places in the lowlands, too, the streams have deeply intrenched themselves in the glacial deposits. Where changes of drainage or of gradient were brought about by the glaciers, the streams have cut in some places and filled in others, in their attempt to reestablish normal stream gradients in their valleys. The shore lines of Cook Inlet have been modified by wave action, and the normal agencies of stream and subaerial erosion have taken up the eternal task of reducing the land masses and filling the depressions.

MINERAL RESOURCES.

The mineral resources of the region to be served by the Alaska Railroad comprise a great variety of metallic and nonmetallic minerals. Some of these have been actively exploited for many years. Others have awaited the lower cost of development and operation that will prevail, now that the railroad is completed. A brief statement of the value of minerals produced from this region up to the end of 1922 is given on pages 76–77. Here, as in most other frontier countries, the earliest prospectors searched for the precious metals, especially for placer gold, for placer gold mining can be done with simple and portable tools, and the metal produced can be easily taken out from even the most remote regions. The first attempt to mine gold in Alaska was made in this region, on the west side of Kenai Peninsula, by the Russians in 1848, but without much success, though they recovered a few ounces of gold. Since the early nineties, however, there has been continuous prospecting, and a number of gold placer camps have been established.

The next stage to follow the search for and exploitation of the gold-bearing stream gravels is the attempt to find the bedrock source of the gold from which the placers have been derived, and there are now a number of districts in this region in which gold quartz mining is carried on. The Willow Creek district has already produced over $2,000,000 worth of lode gold, the Fairbanks district over $1,337,000, and there are promising though as yet little developed gold lodes in Kenai Peninsula, in the Knik-Turnagain Arm district, and in the Yentna, Talkeetna, West Fork of Chulitna, Kantishna, and Bonnifield districts. Like gold placer mining, gold lode mining can be carried on in rather inaccessible regions, for although the cost of transporting such supplies as powder, steel, and machinery to the mine is often very high, the metal recovered, if the ore is free milling, can be taken out without great difficulty. Lode deposits of gold ore in which the gold is not free milling and can not be recovered by amalgamation, and of such other metals as silver and copper, which commonly occur as sulphide ores, can generally not be profitably exploited without fairly good transportation facilities, for not only must all supplies and machinery be brought to the ore deposit, but the heavy ore or concentrates produced must be transported to smelters to be reduced. Many low-grade gold placers also, which require for their working heavy hydraulic equipment, steam-scraper plants, or dredges, are dependent on reasonable transportation costs before they can be developed at a profit. It is obvious that to be mined profitably a mineral deposit must contain sufficient valuable minerals to pay not only the cost of mining and reducing the ore and of getting the product to the

market but a profit to the miner as well. The value of an ore deposit thus depends to a large degree upon its location in respect to routes of transportation, as well as upon its metal content, and an inaccessible ore deposit that would have great value if cheap transportation to it were available may be worthless. The completion of the Government railroad from Seward to Fairbanks has greatly improved the transportation to a large number of mines and prospects in this region and should make profitable the exploitation of many mines whose development could heretofore not be undertaken. One of the most valuable mineral resources of this region is coal. High-grade bituminous coal is found in Matanuska Valley, and lignite of very fair grade occurs in a great number of localities on Cook Inlet, in Susitna and Chulitna valleys, in the Nenana coal field, and at many places along the north flank of the Alaska Range. All these coal deposits are potentially valuable, but except for supplying small local markets their present value depends upon good transportation more than upon any other single factor. The present development of the coal fields is considered elsewhere in this report.

GEOLOGIC RELATIONS OF MINERAL DEPOSITS.

An important service that the geologist can render to the mining industry is in recognizing and pointing out the relations of the several rock formations to the ore deposits, in determining which rocks are likely to contain valuable minerals and which hold out little promise to the prospector, and in mapping the areal distribution of the different rock formations so that the prospector can choose as the field for his search those areas that are most likely to yield him the reward he seeks. A large part of the region here considered has been mapped geologically (Pl. I) in at least a reconnaissance way, so that the main facts concerning the distribution of the rocks are known. It is therefore pertinent to summarize at this place the salient points in regard to the distribution of the ore deposits and the association of the different kinds of valuable mineral deposits with certain types of rocks. This summary will be given in the general geographic order of the deposits along the railroad from Seward northward into interior Alaska.

CHUGACH-KENAI REGION.[20]

The central and northern portions of Kenai Peninsula are composed mainly of a great series of Paleozoic and Mesozoic rocks, chiefly shale, slate, argillite, and graywacke, with very minor

[20] For a full discussion of the mineral deposits of Kenai Peninsula, see Martin, G. C., Johnson, B. L., and Grant, U. S., Geology and mineral resources of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 587, 1915.

amounts of granitic material and of greenstone. In that region there are a great number of placer mines and prospects; many gold lode prospects, a few of which have been mined; and a large number of copper prospects and one copper mine that has long been one of the large copper producers of the territory. Placer mines contain gold that has been concentrated in the stream beds from some bedrock source, and after the metal particles have been delivered to the stream the relation of the gold to the underlying bedrock at the point where it comes to rest is purely accidental. If the miner can find the veins from which the gold comes, however, and can learn the relation of the veins to their country rock, he is aided in the search both for other similar veins and for the stream placers derived from them.

GOLD LODES.

The gold lodes of the Chugach-Kenai region, as shown on Plate I, may be divided according to their distribution into two main groups—one having a north-south linear arrangement and extending from Resurrection Bay to Turnagain Arm, and the other group being massed around the shores of Port Wells. Throughout both of these groups there is a striking similarity in the geologic relations of the ore deposits, for the gold occurs in veins that cut the slate and graywacke in districts where these sediments have been intruded by granitic or siliceous materials. A few exceptional veins occur in bodies of granite.

In northern Kenai Peninsula there is a series of siliceous dikes that strike in a northerly direction, and the gold lodes bear a striking relation to these dikes. The veins ordinarily consist of a quartz gangue containing, in addition to native gold, the sulphides arsenopyrite, galena, sphalerite, pyrite, pyrrhotite, chalcopyrite, and more rarely molybdenite. In places the ore is very rich and yields fine specimens, but even in the better veins the gold content is irregularly distributed, few mines have been profitably operated, and the total yield from all the gold lodes of the region together has so far not been large.

GOLD PLACERS.

The gold placers of the Kenai Peninsula-Turnagain Arm region are the result of the erosion and concentration by the streams of gold from the lodes, and the ultimate origin of the gold of both lodes and placers is therefore the same. The occurrence of placer gold, however, depends on physiographic processes, the most important of which are long-continued erosion and the concentration by some stream of the gold particles contained in the rock débris into a single

restricted channel. In this region normal stream erosion was for a long time interrupted by the invasion of glacial ice. Probably much richer and more extensive placer deposits existed here in preglacial time, but they were in large part removed and scattered by the glaciers. It is only in especially favored localities that workable placers now exist, either in places that escaped glacial scour or in places where postglacial concentration of gold from the lodes or of scattered gold in glacial deposits has been especially rapid. It is only by close and intelligent prospecting that such localities are likely to be discovered.

The mining of gold placer gravel on Kenai Peninsula has been confined largely to the valleys of the streams draining to Turnagain Arm, though a little mining and prospecting has been done in the basin of Kenai River. Gold is widely distributed and has been found in terrace gravel, glacial deposits, and the present stream gravel. The earliest producing streams of the region were Resurrection Creek, which through much of its length flows through a deep, canyon-like channel,[21] and Palmer Creek, a tributary from the east. Sixmile Creek and its tributaries Canyon Creek and East Fork have also produced considerable gold, and a large hydraulic plant is at present in operation on lower Canyon Creek.

On the north side of Turnagain Arm, in the basin of Crow Creek, a tributary of Glacier Creek, placer mining has long been conducted. On lower Crow Creek an ancient channel containing placer gold has been found deeply buried beneath glacial moraines and gravels. On upper Crow Creek paying placers have been found in a gravel-filled basin lying behind a glacial moraine of coarse boulders and till.

The placer mines of Kenai Peninsula and the Turnagain Arm district have been worked more or less vigorously since about 1894, reached their highest yield between 1897 and 1899 with an annual production of $150,000 to $175,000, and then declined rapidly to less than $40,000 in 1912, since when the annual output has ranged from $20,000 to $40,000. In 1922 about a dozen gold placer mines were operated, with an estimated production of $40,000.

COPPER LODES.

In the Chugach-Kenai region there are only two important areas in which copper lodes occur, one just east of Resurrection Bay and the other farther east, on the islands of Prince William Sound and centering at Latouche. An examination of the accompanying geologic map (Pl. I) at once draws attention to the fact that in both of these areas the copper lodes are associated with bodies of green-

[21] Moffit, F. H., and Stone, R. W., Mineral resources of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 279, pp. 33–48, 1907.

stone, which occur either as intrusive masses or as lava flows. This association of copper deposits with basic igneous rocks interbedded with or cutting sediments is general throughout Alaska. The lodes that lie just east of Resurrection Bay are as yet only prospects, and no systematic mining has been done on them, but the copper-bearing sulphides, mainly chalcopyrite, occur in shear zones in the slate and graywacke and in the greenstone.

The largest and best-equipped copper mine in the Alaska maritime provinces is the property of the Kennecott Copper Corporation, generally known as the Beatson Bonanza mine, on Latouche Island. The extensive ore deposit at this mine, as well as many other copper lode prospects on Latouche and Knights islands, is in the slate and graywacke in a district where these sediments are cut by and interbedded with greenstones. These deposits are described by Johnson[22] as occurring in brecciated or sheared zones in both the sedimentary rocks and in the greenstone of these islands. The ore bodies are primary deposits, the sulphides impregnating or replacing the sediments and greenstone and filling small fractures and openings in the material of the shear zones. The ores are chiefly sulphides in a gangue consisting principally of crushed and altered country rock. The commercially important copper-bearing mineral is chalcopyrite, and it is associated with chalmersite, native gold, silver, pyrrhotite, pyrite, sphalerite, and galena, with locally some arsenopyrite and nickeliferrous pyrrhotite, in a gangue containing quartz, feldspar (?), chlorite, ankerite, calcite, and epidote. The only large producing mine in this group, that of the Kennecott Copper Corporation, has been actively exploited for years and has produced a large amount of copper.

Considerable development work has been done on a number of other properties, and it is likely that some of them will become mines.

TALKEETNA MOUNTAINS.

As has already been shown, the outstanding feature of the geology of the Talkeetna Mountain region is a group of large and small granitic intrusive masses and smaller amounts of basic intrusives and flows with associated fragmental volcanic materials, the igneous materials intruding or overlying sediments that range in age from early Paleozoic or older to Tertiary. Plates I and II show the salient facts about the areal geology of the western Talkeetna Mountains and the location of the mines and prospects. Metal mining in this region has been limited to gold placer mining at a number of localities and to the exploitation of the gold lodes of the Willow

[22] Johnson, B. L., Geology and ore deposits of Latouche and Knight islands and vicinity, Prince William Sound, Alaska: U. S. Geol. Survey Bull. — (in preparation).

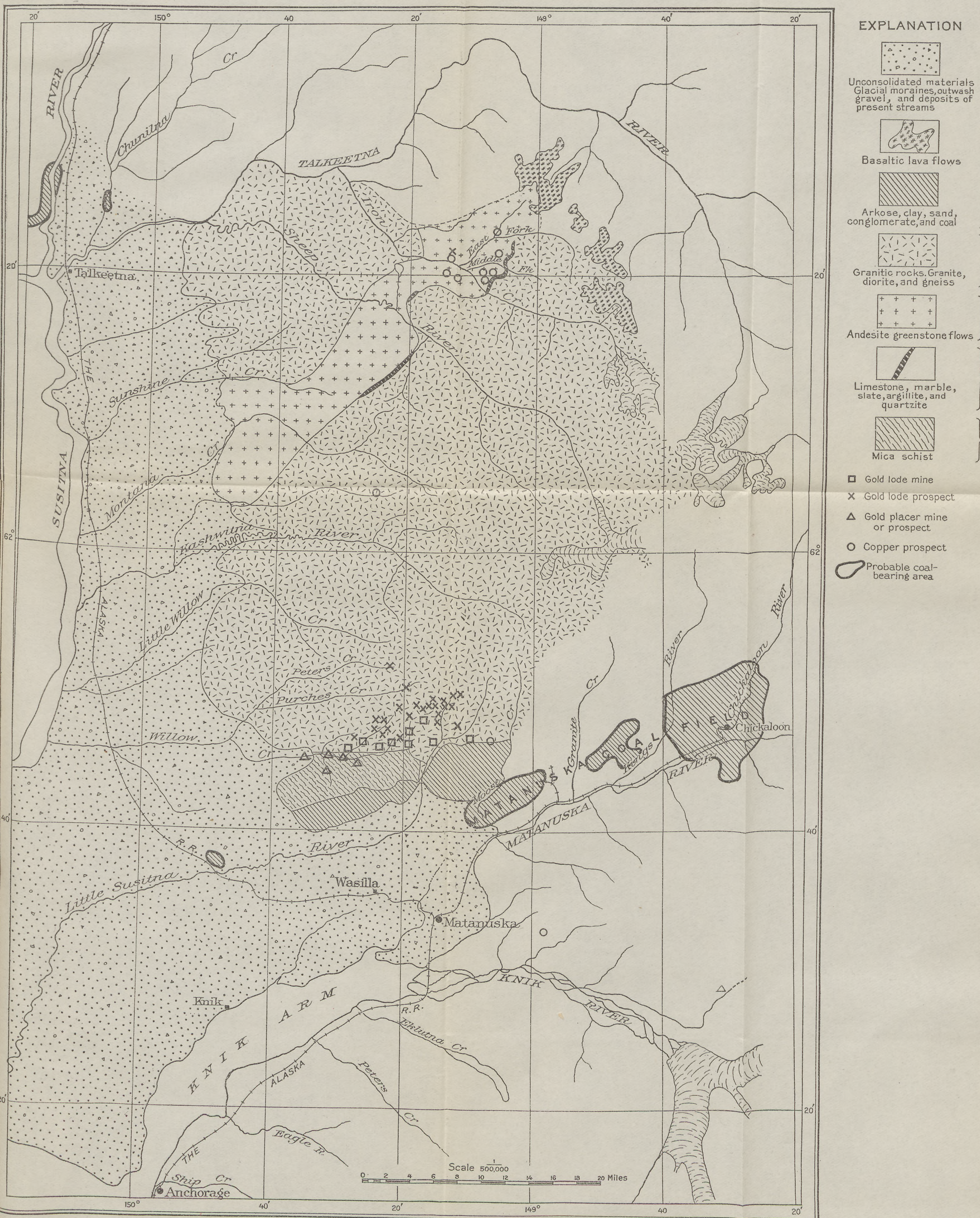
Creek district. There are, however, many other districts in which are found lode prospects, including lodes carrying gold, copper, and antimony, that may be developed into producing mines. In addition to the Willow Creek gold lode district, the principal areas that have promising ore deposits are the Iron Creek district, with its numerous copper prospects, and the Nelchina gold placer district. The high-grade coals of Matanuska Valley and the lignite deposits of Susitna and Chulitna valleys are described in another section of this report.

GOLD LODES.

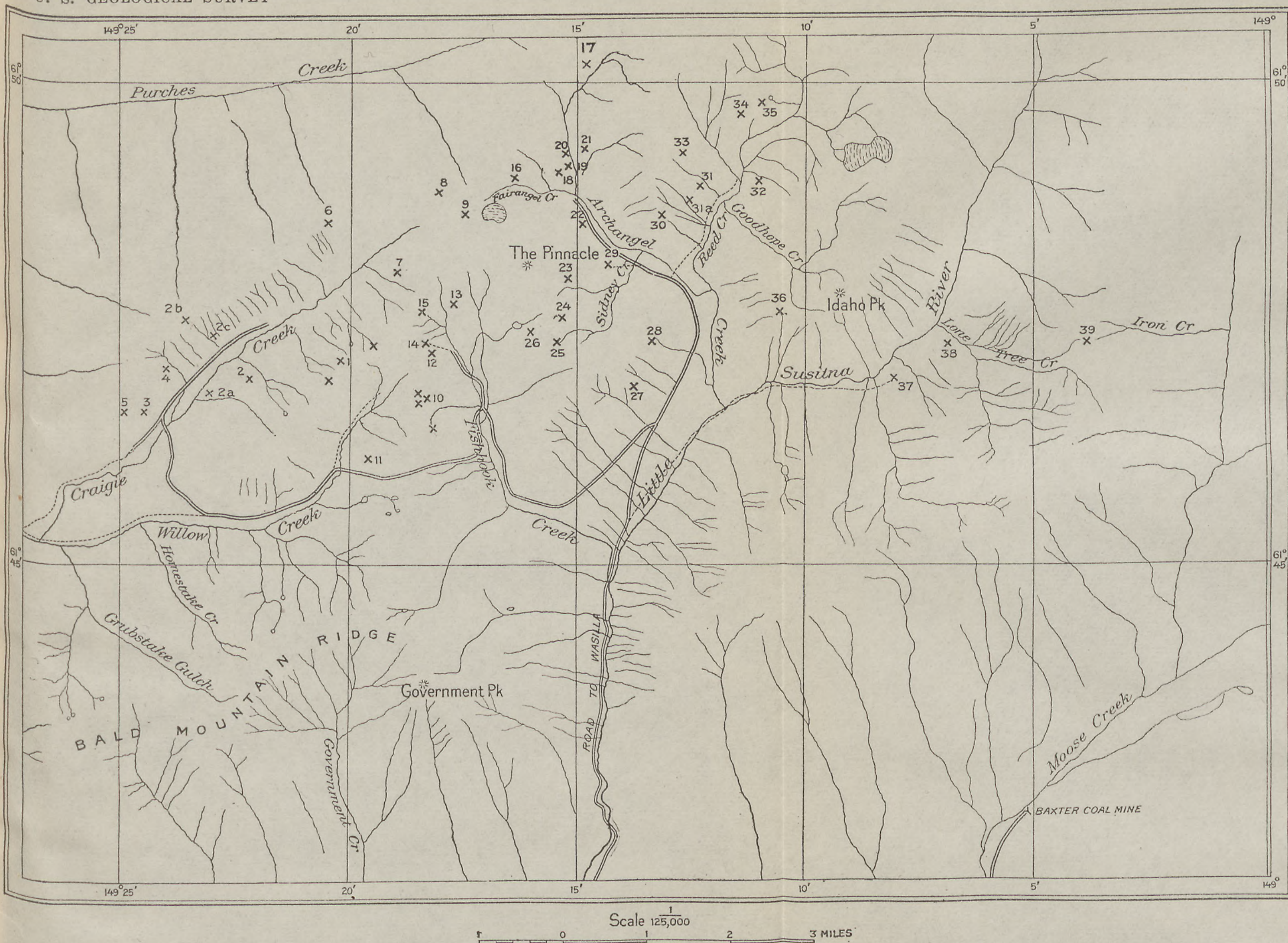
Willow Creek district.—The gold lodes of the Willow Creek district constitute by far the most important developed metal resources in the Talkeetna region. From 1908 to 1922 these lodes yielded over $2,194,000 worth of gold and silver, and the output in 1922 was worth $239,500. These lodes consist of quartz veins which cut quartz diorite.[23] The diorite is generally massive, coarse grained, and little altered but in places is somewhat schistose. Most of the veins strike in a general north-south direction, and they dip westward at an average angle of 39°. The veins are in sharp, clean fissures in quartz diorite. They probably represent fillings of early joint planes and are now paralleled and intersected by other sets of joints that have no vein filling. Ore has been deposited in some of the veins at repeated intervals, as is witnessed by the banding of the ore. Some movement has taken place since the ore was deposited, resulting in shearing, faulting, and the formation of gouge along many of the veins.

The gold is present in the veins largely as native gold, and much of it is recoverable directly by amalgamation. The tailings carry some gold entangled in the pyrite, which is generally treated by cyanidation. Associated with the gold in the veins are the metallic minerals pyrite, arsenopyrite, stibnite, chalcopyrite, bornite, chalcocite, galena, malachite, limonite, and cinnabar. Except for the limonite and malachite, which are plainly secondary after pyrite and chalcopyrite, and the cinnabar, which was introduced after the gold mineralization, the assemblage of minerals listed is characteristic of gold-bearing veins of deep-seated origin, deposited by aqueous solutions. The district lies in an area of severe Quaternary glaciation, and the oxidized zone is very shallow. Most of the ore mined is primary ore. The accompanying sketch map (Pl. III) shows the distribution of both gold lode and gold placer mines and prospects in the Willow Creek district. The above description of the character of the veins probably applies also to a number of veins farther

[23] Capps, S. R., The Willow Creek district, Alaska: U. S. Geol. Survey Bull. 607, pp. 55–60, 1915.



GEOLOGIC SKETCH MAP OF THE WESTERN TALKEETNA MOUNTAINS.



SKETCH MAP OF WILLOW CREEK DISTRICT, SHOWING LOCATION OF LODE MINES AND PROSPECTS.

1. Gold Bullion mine.
2. Golden Light prospect.
2a. Rainbow prospect.
2b. Golden Top prospect.
2c. Comeback prospect.
3. War Baby mine.
4. Panhandle prospect.
5. Lucky Shot mine.
6. Gold King prospect.
7. Newman & Miller prospect.
8. Dixie prospect.
9. Little Willie prospect.
10. Brooklyn-Willow Creek Gold Mining Co.
11. Mammoth prospect.
12. Alaska Free Gold mine.
13. Gold Cord mine.
14. Independence Gold Mines Co.
15. Kelly-Willow Creek Mining Co.
16. Consolidated Mining Co.
17. Anchorage Gold Mines Co.
18. Rutland prospect.
19. Fern & Goodell prospect.
20. Giant Gold Mining Co.
21. Little Gem Gold Mining Co.
22. Webfoot prospect.
23. Mohawk prospect.
24. Keystone prospect.
25. Smith-Sargent prospect.
26. Rae-Wallace mine.
27. Shough prospect.
28. Mabel mine.
29. Arch prospect.
30. Opal prospect.
31. Idamar prospect.
31a. Home Builder prospect.
32. Mary Ann prospect.
33. Snow King prospect.
34. Willow Creek Development Co.
35. ——— prospect (idle).
36. Le Roi Mines Co.
37. Gold Mint mine.
38. Maverick prospect.
39. Moose Creek copper claims.

north, in the Peters and Purches creek basins, that have not been studied.

Iron Creek district.—A lode in the Iron Creek district that is valuable chiefly for its gold content occurs under the same conditions as the copper lodes in that vicinity. It carries copper also and is described below. The Iron Creek district lies some 40 miles by trail west of the railroad at Talkeetna, in the basin of Iron Creek (Pl. II). Stated in simplest terms, the rocks of this district include a sedimentary series of limestone, marble, slate, argillite, and quartzite, cut and overlain by basic dikes and flows, and both sediments and basic rocks extensively intruded and surrounded by great masses of granitic rock. Some basaltic lava flows are also present.

COPPER LODES.

The following description of the lodes of the Iron Creek district is based on an examination made in 1917.[24] As no geologist of the Geological Survey has visited the district since that time, and as the edition of the report on it is exhausted, the lodes are here described in greater detail than would be given if the literature on them were more voluminous or more easily accessible. The position of the lodes and the general distribution of rock formations of the district are shown on Plate II.

The principal valuable minerals of the lodes are copper and gold. Most of the ore bodies are due to the replacement, along zones of faulting and shearing, of andesite greenstone, but one or two, also in andesite greenstone, have some of the aspects of contact-metamorphic deposits, though they lie some distance from the contact of diorite that intrudes the greenstone. So far as is known the content of the ores in free gold is not sufficient to justify milling them on the ground. The base character of the ore will necessitate smelting for the recovery of the copper and gold. Hence cheap transportation to a smelter is essential before these lodes can be developed.

Copper Queen group.—The Copper Queen group includes two claims that lie on the north side of Iron Creek, 2 miles below the mouth of East Fork. Developments at the time of visit had been confined to stripping the vegetation from the ore body and the excavation of a shallow open cut. The country rock is an andesite greenstone with amygdules of greenish-yellow epidote. The ore body, which lies along a sheared and crushed zone that strikes N. 10° E. and stands nearly vertical, has been formed by the replacement of the sheared andesite, which is heavily mineralized throughout a width of 21 feet across the strike, though there are many large

[24] Capps, S. R., Mineral resources of the western Talkeetna Mountains: U. S. Geol. Survey Bull. 692, pp. 187–207, 1919.

lenticular horses of nearly barren country rock. Pyrite, arsenopyrite, and chalcopyrite are the common metallic minerals and occur as nearly pure masses of one or the other of these sulphides or intimately intergrown with one another. Some quartz is present in the ore as gangue but is not abundant. Scattered specks and blotches of sulphides occur both in the horses within the ore body and in the wall rock for some distance back from the zone of shearing. This lode is unusual in this district in that assays of ore from it are said to show a high gold content, so that its value for gold probably exceeds its value for copper.

Copper King group.—The Copper King group comprises six claims that lie on the south valley wall of Iron Creek opposite the mouth of East Fork. The principal workings are at an altitude of about 3,300 feet, 1,500 feet above the valley bottom, and consist of a number of trenches and open cuts excavated to demonstrate the presence of a long, continuous ore body. They show that the andesite greenstone country rock is cut by a shear zone that strikes northeast and dips about 60° E., in which the sheared material has been replaced in part by metallic minerals and some quartz. The shear zone ranges in width from 6 to 20 feet, and the degree of replacement of the sheared andesite greenstone differs greatly from place to place. The best showing of ore was in a large open cut that had been excavated down to undisturbed bedrock. In this cut, through a width of 9 feet across the strike of the shear zone, abundant chalcopyrite and specular hematite with some pyrite and a little quartz were exposed. The ore is banded parallel to the direction of the shear zone and consists of alternating bands of nearly pure chalcopyrite, specular hematite intergrown with quartz, and pyrite. The individual bands are more or less discontinuous, and the characteristic mineral of one band may be present in small amounts in the other bands. Another cut near by shows several feet of nearly pure hematite with only small amounts of other sulphides. Locally some quartz is present in the shear zone in small distinct veins. The ore from this group of claims is said to carry only small amounts of gold and silver.

Copper Wonder group.—The Copper Wonder group comprises seven claims that lie on the south slope of Iron Creek valley south of the mouth of Middle Fork. These claims were first staked in June, 1917, and the only development work done by August of that year was the excavation of three open cuts in the bluffs of Alder Gulch, at an elevation of about 2,500 feet. These cuts show a zone of strong shearing in andesite greenstone country rock, but the ground has been much disturbed, and in the shallow excavation the strike and dip of the shear zone could not be definitely determined. In the larger open cut the andesite greenstone is seen to be much

altered along the shear zone, in which there is a heavy deposit of specular hematite, together with some pyrite and bunches of chalcopyrite as large as a man's fist. A little quartz was also noted as a gangue mineral. The hematite has a thickness of 2 to 3 feet through an exposed vertical distance of 20 feet, and there is considerable copper carbonate stain in the altered shear-zone material. Scattered specks of sulphides were seen in the andesite country rock outside of the shear zone.

Phoenix group.—The Phoenix group includes three claims on Hyphen Gulch, a small tributary of Iron Creek from the northeast, a little more than a mile above the mouth of Middle Fork. The only locality at which any noteworthy excavation had been made was at an altitude of 3,600 feet, where an open cut showed a small shear zone, 2 to 3 inches wide, in andesite greenstone. This shear zone, or line of faulting, strikes S. 30° W. and dips 65° NW. It contains gouge and decomposed materials, with a little quartz and some copper carbonate stains. The andesite greenstone wall rock is, however, much stained with copper carbonate and has locally been partly replaced by chalcopyrite, bornite, specular hematite, and quartz. The bornite is closely associated with chalcopyrite and is apparently a surface occurrence only, for a shallow excavation made at the best showing of bornite showed little bornite at a depth of a few feet below the surface but an increasing abundance of chalcopyrite. A number of narrow veins of nearly pure hematite with small quantities of associated sulphides have been found on this property.

Blue Lode group.—The Blue Lode group of five claims lies on the south side of the valley of Middle Fork of Iron Creek, about 2½ miles above the mouth of that stream and 1 mile northeast of the Phoenix group. The principal excavation is at an altitude of 4,200 feet, where a large open cut has been made along a fault or shear zone about 2 feet wide that strikes N. 16° E. and dips 80° W. This zone is filled with gouge, fine crushed and decomposed material, and some quartz that contains chalcopyrite. The wall rock of this shear zone is andesite greenstone, which has locally been replaced by specks and bunches of bornite and chalcopyrite. An andesite greenstone cliff above the excavation shows abundant stains of azurite and malachite. Broken surfaces of the surface wall rock show bornite and chalcopyrite intimately intermingled, but a few feet below the surface the bornite becomes relatively scarce and chalcopyrite predominates, suggesting that the bornite occupies only a shallow zone of enrichment and that at greater depth the chalcopyrite will prove to be the prevailing sulphide. Another open cut farther down the mountain shows chalcopyrite but no bornite. This property was staked only a few weeks before it was visited, and too little

development work had been done to determine either the size of the ore body or its character at depth.

Eastview group.—The Eastview group of two claims lies in the basin of Middle Fork of Iron Creek half a mile southeast of the Blue Lode group and about the same distance northeast of the Phoenix, at an altitude of 4,500 feet. The country rock is andesite greenstone, and the workings include three open cuts, from which have been taken large lumps of banded quartz, hematite, and chalcopyrite. In these lumps of ore chalcopyrite is locally abundant, but as none of the cuts had been carried down to undisturbed bedrock at the time of the writer's visit, no ore in place was seen, and nothing is definitely known about the size or position of the ore body.

Talkeetna group.—The Talkeetna group of nine claims lies in the valley of Prospect Creek, about 2 miles above the mouth of that stream. The claims were staked in the spring of 1916, and their exploration and development had been limited to strippings and open cuts made in the endeavor to show the character of the ore in place. At the time of the writer's visit eight men were employed on this property. The main ore body is on the claim known as Talkeetna No. 2, where an extensive gossan on the steep mountain slope, at an altitude of 4,200 feet, renders the ore deposit conspicuous from a distance. A number of trenches and open cuts have been excavated through this gossan, but these were made for the purpose of ascertaining the character of the unoxidized ore body, and no consistent effort had been made to outline the area of mineralization or to determine its structure and relations. The country rock is an amygdaloidal andesite greenstone, and the amygdules consist of epidote. This greenstone is cut by a shear zone that strikes approximately east and dips 75° N. The shear zone has acted as a channel for the circulation of mineralizing solutions, and the sheared material, as well as the massive wall rock, has been in part replaced by specular hematite, chalcopyrite, pyrite, and quartz. The area of intense mineralization, so far as could be determined from the workings, is several hundred feet long and is locally at least 30 feet thick. Its long dimension is parallel to the strike of the shear zone, which itself lies almost parallel to the steep mountain face, so that the ore is exposed on the surface through a vertical distance of at least 50 feet. The gossan is only a few feet thick and is abundantly stained with copper carbonate.

Specular hematite is by far the most abundant metallic mineral and occurs in massive aggregates many feet thick, in which the only other conspicuous mineral is granular quartz that is intimately intergrown with the hematite. Another abundant type of ore consists of an intergrown aggregate of hematite, chalcopyrite, and

quartz that forms the matrix of a breccia and surrounds angular fragments of andesite greenstone, themselves partly replaced by iron and copper minerals. Elsewhere the ore consists of sheared and schistose andesite greenstone largely replaced by metallic minerals and banded with small quartz veinlets that include the same minerals—pyrite, chalcopyrite, and hematite. Veinlets of ore shoot off from the main ore body into the country rock, and sulphides and hematite are widely disseminated in the country rock for some distance on both sides of the shear zone. These claims are being prospected as a source of copper, and a large amount of work must be done before a proper estimate can be made of the amount of copper ore of any particular grade that is available. The principal copper mineral, chalcopyrite, differs greatly in abundance from place to place within the ore body. Locally hematite is present to the almost complete exclusion of the sulphides. Elsewhere chalcopyrite forms the bulk of the ore. In some places the chalcopyrite crystals are surrounded by a thin zone of hematite, and that by quartz. It is reported that assays show from less than 1 per cent to 8 per cent of copper and small amounts of gold and silver. Underground exploration alone can determine the character and metallic content of this ore body at depth, but the great size of the deposit may make possible the development of a mine, even if the ore is of comparatively low grade.

Shallow excavations have been made on croppings of metallic minerals on claims No. 3 and No. 7 of this same group, on the north side of Prospect Creek, where a number of open cuts, for the most part shallow and in disturbed ground, show similar ores, which have the same association of pyrite, hematite, and chalcopyrite.

OTHER PROSPECTS.

A number of claims or groups of claims, in addition to those described above, have been staked in the basin of Iron Creek, but on most of them little work had been done, and the restrictions of time imposed upon the writer made it possible to visit only those properties that had been best developed. The location of some of these groups is shown on the accompanying map (Pl. II). Vigorous prospecting in this district has been carried on only since the spring of 1916, and many of the claims were staked in 1917, so that the amount of work that has been done on any property is not necessarily an index of the value of the ore deposit, and some of the properties not visited and not described specifically may be of greater merit than some of those that are more fully described here. The possibilities for the discovery of still other ore deposits in this area have by no means been exhausted, and it is likely that

other ore bodies more valuable than any yet discovered may be found. A large area in the basins of Sheep River, Montana Creek, and Kashwitna River has received scant attention. Hand specimens of rich copper and gold ores have been brought out from this area by prospectors, but the localities from which they came could not be learned, and the deposits were not visited by the writer. Later in the summer of 1917 reports were circulated of the discovery on a northward-flowing tributary of Talkeetna River, opposite the upper basin of Iron Creek, of a large dike whose surface croppings yielded gold upon panning and which was said to show an encouraging gold content upon assay.

NELCHINA DISTRICT.

The Nelchina district lies at the eastern border of the region here considered, on the eastern flank of the Talkeetna Mountains, in the basin of Nelchina River, whose waters reach Copper River by way of Tazlina Lake and Tazlina River. The portion of the accompanying sketch map (Pl. I) showing the general geology and the location of the gold placer prospects in this district is taken from the first published description of this region by Chapin,[25] and the description here given is abstracted from that and a later more complete report by the same author.[26] The geologic formations in the neighborhood of the gold-bearing gravels include Jurassic and Cretaceous conglomerate, limestone, sandstone, and shale, associated with Jurassic andesitic greenstone and various Tertiary lavas. Extensive Quaternary deposits of glacial and fluviatile origin pave the valley floors and the entire Copper River basin, to the east.

The only known mineral resources of this district are the deposits of auriferous gravel that have received considerable attention in the last eight or nine years. Gold has been found in encouraging amount only in a small area, confined to the tributaries of Little Nelchina River, Tyone Creek, and Oshetna River. (See Pl. I.) So far little gold has been recovered in this district.

The bedrock source of the placer gold is obscure, but it is believed that most of the gold has been brought to the neighborhood where it is now found by glaciers, and that the placers have been formed by the postglacial concentration by streams of the gold scattered through the glacial deposits.

Crooked Creek, a tributary of Little Nelchina River, has yielded little gold but has locally been vigorously prospected. On one claim a shaft was sunk to a depth of 180 feet, in 1914, without reaching bedrock.

---

[25] Chapin, Theodore, Auriferous gravels of the Nelchina-Susitna region: U. S. Geol. Survey Bull. 622, pl. 6, 1915.

[26] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, 1918.

On Albert Creek some mining was done in poorly stratified gravel that overlies a bedrock of tuffaceous sandstone and shale, associated with volcanic rocks. The gold was found to be scattered through the gravel, with little or no concentration on bedrock. A few thousand dollars' worth of gold is said to have been taken from this stream valley.

Considerable prospecting has been done from time to time on Little Nelchina River, Poorman, Yacko, Fourth of July, and Daisy creeks and Oshetna River, without finding any large deposits of workable ground. A few prospectors retain their faith in this district, and some prospecting and mining is done there each year.

MATANUSKA COAL FIELD.

Within the lower basin of Matanuska Valley there is an extensive coal field that has been widely credited as constituting one of the country's greatest coal reserves on the Pacific coast. The existence of this coal field was largely responsible for the first attempt to build a railroad from Seward northward into interior Alaska and had a large influence in determining the route for the Alaska Railroad.

The coal-bearing beds in Matanuska Valley[27] all occur in the Chickaloon formation, a series of shale and sandstone of Tertiary, probably Eocene age, which is underlain by Tertiary arkose, shale, and conglomerate and overlain by later Tertiary conglomerate. The whole series is intruded by numerous bodies of igneous rocks that include andesite, gabbro, diabase, and diorite, in fairly large masses, and by many dikes and sills.

The coals of Matanuska Valley range in grade from low-grade bituminous to high-grade bituminous. The low-grade bituminous coals are found in the valleys of Young, Eska, and Moose creeks; the high-grade bituminous coals in the valleys of Chickaloon and Kings rivers and on the south side of Matanuska River in the vicinity of Coal Creek. All these coals are probably of about the same age, their difference in character being due to differences in the amount of metamorphism which the beds have undergone from place to place. The lowest-grade bituminous coals are least folded, faulted, and intruded, and their poorer quality is in a measure offset by the ease and cheapness with which they can be mined. The high-grade bituminous coals have been more severely folded, faulted, and intruded.

Prospecting on these coal beds was begun 20 years ago, and in the spring of 1913 a shipment of several hundred tons was mined

[27] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, 1912. Chapin, Theodore, Mining delevopments in the Matanuska coal field: U. S. Geol. Survey Bull. 712, pp. 131–168, 1920.

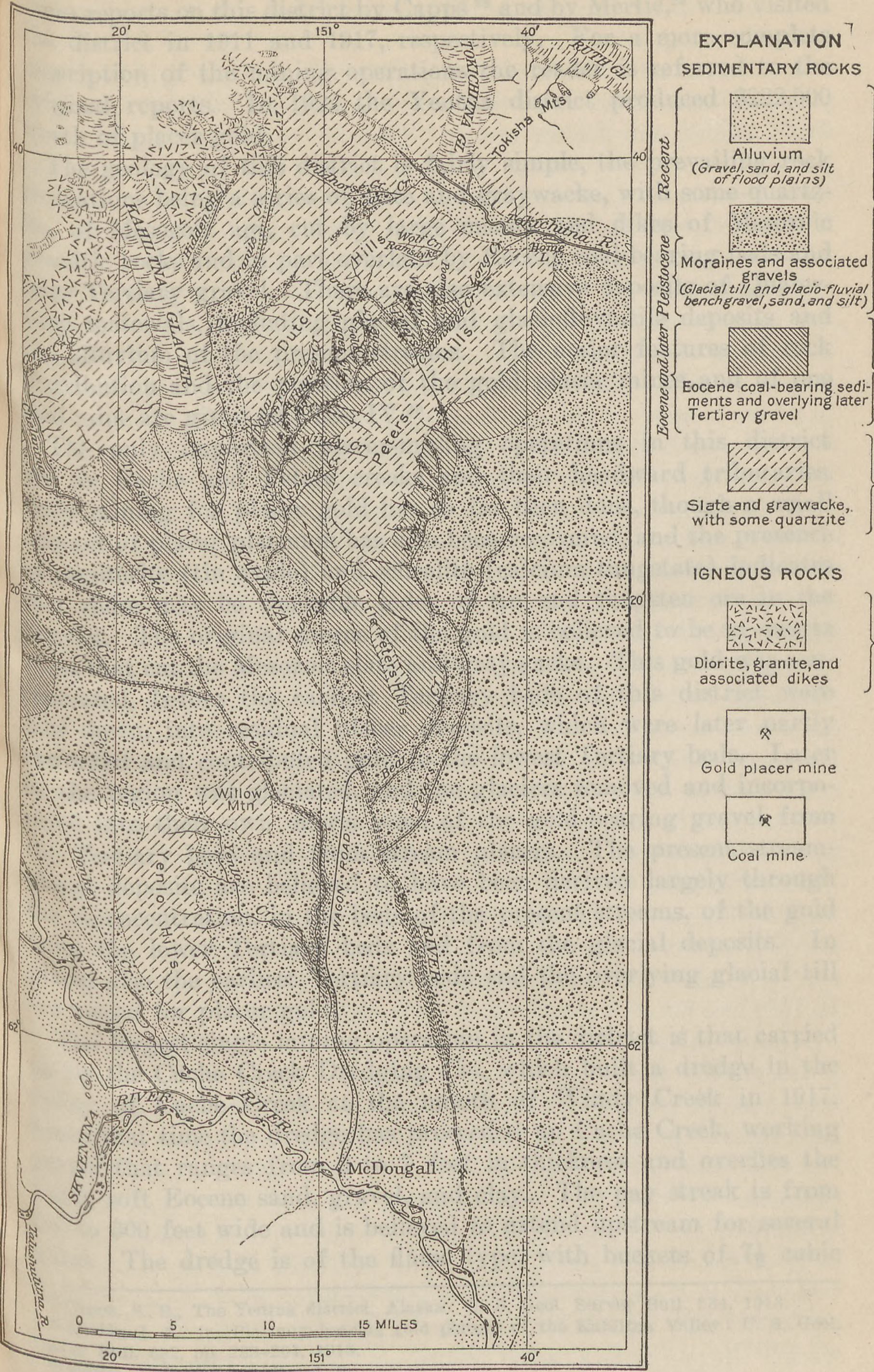
and tested by the U. S. Navy. With the commencement of construction on the Alaska Railroad, in 1915, prospecting became more vigorous and mining was begun, with a view to supplying fuel for the railroad. Up to 1922 the Matanuska field has produced over 305,000 tons of coal, a considerable part of it from mines operated by the Government. A large amount of prospecting has also been done. Although high-grade bituminous coals exist at many places in the valley, the beds so far exploited are so much faulted and broken that the cost of mining has remained high. Prospecting for more favorable beds, where mining can be done more cheaply, will continue. In the meantime the lower grade but more easily mined coals will continue to supply the needs of the railroad and other local demands.

Large areas in the Matanuska coal field are still insufficiently prospected to justify a statement as to the area of coal there that is minable under present conditions. Certainly there is a large tonnage of coal available. Whether or not any particular area there can be mined will depend on the relation between the cost of mining, and the cost of competing fuels. With abundant cheap fuel oil on the Pacific coast, and plentiful, more cheaply mined coals of lower grade available along the Alaska Railroad, the higher grade but more difficultly mined coals of the Matanuska Valley may be unmarketable. Yet, if a sufficient demand for high-grade coal arises, these coals may be mined to supply needs that can not be met by the cheaper fuels.

Exposures of lignitic coal are known to occur at intervals around the entire margin of the Cook Inlet-Susitna basin, from lower Cook Inlet to Broad Pass, and the number of localities at which this coal has been found is steadily increasing. The distribution of these coal localities and the attitude of the beds there indicate that coal-bearing Tertiary beds are of widespread distribution in this basin, and that they contain an enormous tonnage of lignite. At present this fuel has little value for other than local uses, but the time may come when it can be mined and sold at a profit.

YENTNA DISTRICT.

The Yentna district is on the southeast flank of the Alaska Range, 40 miles west of the town of Talkeetna, from which it can be reached by a wagon road and trail. This district has yielded a steady and increasing production of placer gold since its discovery, in 1905, and the successful operation of a dredge there in recent years gives encouragement for the belief that it will long continue to be a productive mining camp. The following brief notes are abstracted



GEOLOGIC SKETCH MAP OF THE YENTNA DISTRICT.

from reports on this district by Capps [28] and by Mertie,[29] who visited the district in 1911 and 1917, respectively. For a more complete description of the mining operations the reader is referred to the original reports. In 1922 the Yentna district produced $222,000 worth of placer gold.

The geology of this district is fairly simple, the prevailing rock formations being a series of slate and graywacke, with some quartzite, of Mesozoic age, cut by large masses and dikes of Mesozoic granitic rocks and in part overlain by Eocene coal-bearing beds and later Tertiary gravel. There are also extensive deposits of Quaternary materials, including glacial and glaciofluviatile deposits and the alluvium of the present streams. The major features of rock distribution and the position of the gold placer mines and of one coal mine are given on Plate IV.[30]

The only important placer-mining operations in this district are on Cache and Peters creeks and their headward tributaries. Only mining for placer gold has so far been done, though a small amount of placer platinum has also been recovered, and the presence of cassiterite (tin oxide) and scheelite (calcium tungstate) indicates that there may be workable lodes of tin and tungsten ore in the district. The original source of the gold is believed to be in quartz veins that cut the Mesozoic slate and graywacke. This gold was concentrated, before the earliest Tertiary beds of this district were laid down, into residual placer deposits, which were later partly reworked and contributed gold to the lowest Tertiary beds. Later on the region was glaciated, and the glaciers removed and incorporated into their own débris some of the gold-bearing gravel from the Tertiary beds and from stream placers. The present stream-placer deposits are believed to have been derived largely through the reconcentration, in the beds of the present streams, of the gold from the lower Tertiary beds and from the glacial deposits. In places also the earliest Tertiary beds and the overlying glacial till are mined for placer gold.

The largest single mining operation in the district is that carried on by the Cache Creek Dredging Co., which built a dredge in the valley of Cache Creek at the mouth of Windy Creek in 1917. Since that time the dredge has proceeded up Cache Creek, working gravel that ranges from 3 to 7 feet in thickness and overlies the fairly soft Eocene sand, gravel, and clay. The pay streak is from 150 to 300 feet wide and is believed to extend upstream for several miles. The dredge is of the flume type, with buckets of 7½ cubic

[28] Capps, S. R., The Yentna district, Alaska: U. S. Geol. Survey Bull. 534, 1913.

[29] Mertie, J. B., jr., Platinum-bearing gold placers of the Kahiltna Valley: U. S. Geol. Survey Bull. 692, pp. 233–264, 1919.

[30] Mertie, J. B., jr., op. cit., pl. 6.

feet and a daily capacity of 2,000 cubic yards. It is operated by hydroelectric power.

A number of hydraulic mining plants have been operated each year on Cache Creek and its principal tributaries, Nugget, Thunder, Falls, Short, and Dollar creeks. Thunder Creek has usually supported two or three mining plants, and about that number of operations have been conducted each year on the other tributaries named. The magnitude and number of these operations are limited by the amount of water available for the hydraulic nozzles.

For a number of years the principal mining on Thunder Creek has been done by a large hydraulic plant, which has been engaged in sluicing the stream and bench gravels of that stream. The bench gravel mined at places reaches a thickness of 80 feet. The bedrock in places consists of the coal-bearing Eocene formation, though elsewhere a much weathered phase of the underlying slate and graywacke projects through the coal-bearing beds.

A very interesting condition is displayed by the placer excavations on this creek. Associated with the coal-bearing formation are two well-defined beds of quartzose material, each averaging about 12 feet in thickness, consisting of angular or only partly rounded fragments of quartz in a matrix of white clayey material that proves to be a siliceous clay. In this material there are also fragments of coal. The quartzose seams carry considerable gold and have been mined for their gold content. They are evidently of Tertiary age and present the unusual condition of a placer-gold concentration in an early Tertiary sedimentary series that is sufficiently rich to justify mining by hydraulic methods. Two mines are reported to have been operated on Thunder Creek in 1921.

Placer mining has been done on Falls Creek for many years, with varying degrees of activity. In 1917 two plants, employing five men altogether, were operated, one on a bench about 35 feet above the creek and the other on the creek gravel at the mouth of the canyon. In 1921 two mines were in operation in this valley.

Mining operations on Dollar Creek have been carried on for many years, mainly by a single mining company. Most of the work has been done on claim No. 1 above Discovery, where on the east side of the creek there is a high bench in which the conditions somewhat resemble those on Thunder Creek, above described. A hard bedrock composed of slate and graywacke is overlain by a gold-bearing stratum of Tertiary quartzose material, which in turn is overlain by a body of gravel and glacial clay. The quartzose stratum is about 60 feet thick in the middle of the cut and contains about equal amounts of imperfectly rounded to angular fragments of quartz and graywacke. At one place a bed of lignite was seen lying upon this deposit,

thus indicating its Tertiary age. The gravel above the quartzose stratum contains considerable gold, and the glacial clay a little, but most of the gold here recovered comes from the quartzose deposit. Mining is done by hydraulic means, with water under a head of 200 feet. Two properties are said to have been operated on Dollar Creek in 1921.

Some hydraulic mining is done on Windy Creek, a westward-flowing tributary of Cache Creek, on a bench deposit that consists of 40 to 60 feet of gravel overlain by 100 feet of glacial clay. The gold occurs mainly in the lower portion of the gravel, and its concentration therefore preceded the last glacial ice advance. The gravel overlies the coal-bearing formation. In this gravel some pyrite, arsenopyrite, and magnetite and a little cassiterite, native copper, and scheelite are found.

Placer mining by pick and shovel methods was done in 1921 on Short and Gold creeks, both tributaries of Cache Creek from the west. In the Peters Creek basin placer mining has been carried on for many years more or less continuously. Gravel has been worked above, in, and below the canyon through the Peters Hills. The largest operations have been on the stream gravel and benches near the mouth of the canyon. In 1921 two hydraulic mines, employing 12 men, were operated on Peters Creek and made a considerable production of gold. No details are at hand regarding the exact localities of these workings.

On Poorman Creek, a tributary of Cottonwood Creek in the headward basin of Peters Creek, one small placer mine was operated by pick and shovel methods in 1921. The placer gravel of this stream contains appreciable amounts of platinum. In the same year one mine was worked on Willow Creek, also a tributary of Cottonwood Creek, by the use of water under pressure. The Willow Creek placers yield considerable cassiterite, though not in commercial quantities. Bird Creek, a tributary of Peters Creek from the west, has been mined more or less regularly for many years, but the individual operations have been small. Placer mining has been carried on from time to time at many other places in the Yentna district. The bars of Lake Creek and Kichatna River have yielded considerable placer gold, and Mills and Twin creeks, tributaries of Labor Creek, still contain a good deal of unworked placer ground, but mining there is difficult on account of the meager supply of water. There is much ground on Kahiltna River, near the mouth of Cache Creek, and on Peters Creek below the canyon that contains placer gold and may sometime prove to be rich enough for dredge mining.

As has been stated, the Eocene coal-bearing formation is widely distributed in the Yentna district and at a few places is known to

contain lignite beds of workable thickness. On Cache Creek near the mouth of Short Creek a coal bed has been worked to supply fuel for a gold dredge and for other local uses. The coal is of about the same quality as that found generally throughout the Susitna and Chulitna valleys and in the Nenana coal field. Coal from the Yentna district will probably never find any but a local market.

UPPER CHULITNA REGION.

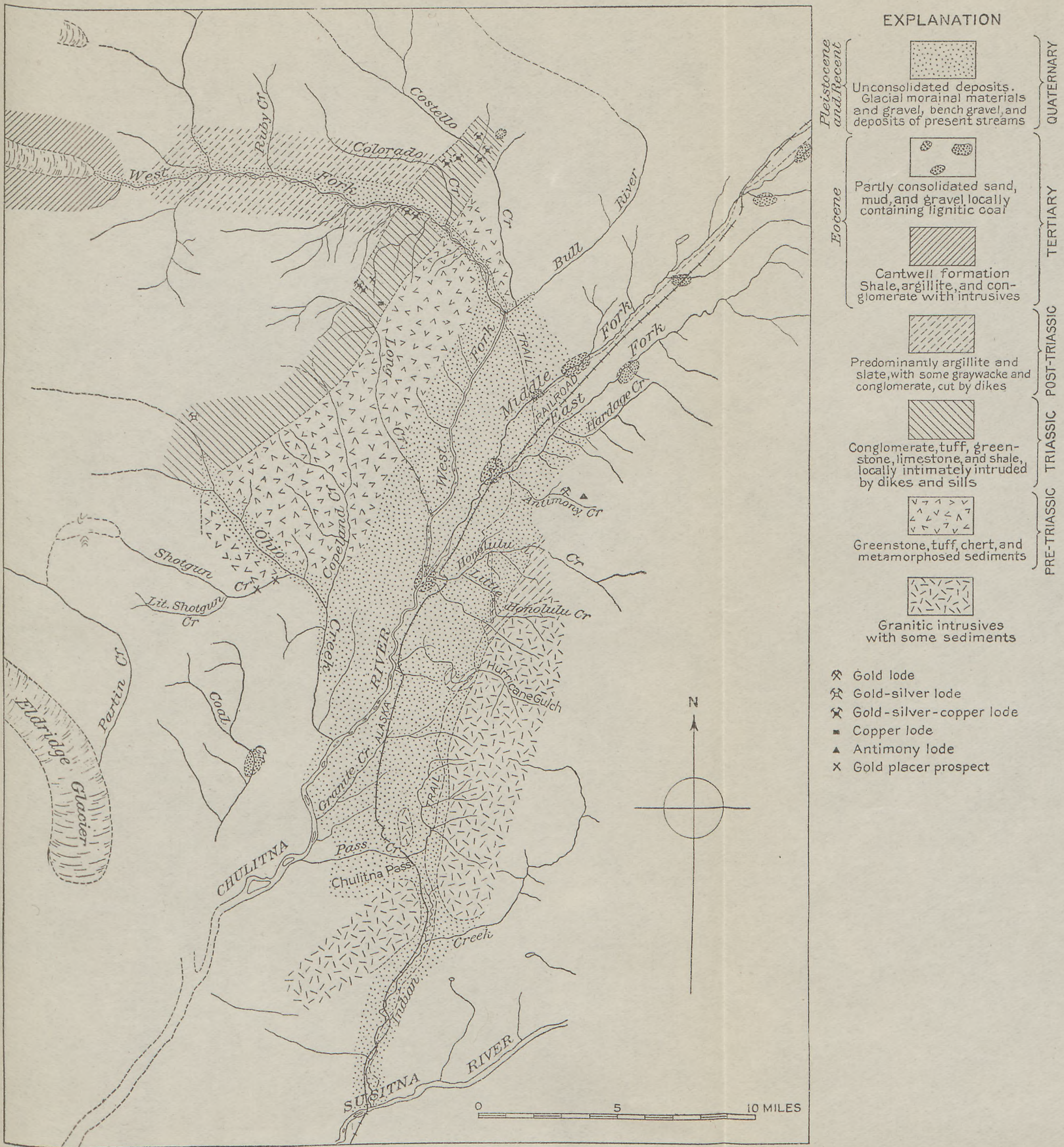
The headwater region of Chulitna River, often referred to as the Broad Pass mining district, contains copper and gold bearing lodes on which prospecting has been done for many years. Most of these lodes lie in the basin of West Fork of Chulitna River, only 6 or 8 miles west of the railroad. The original prospecting in this country was done under great difficulty, for before the railroad was built the region was remote and difficult of access, and prospecting, especially the driving of rock tunnels and shafts on lode deposits, was expensive. Now that railroad transportation is brought close to these prospects they are sure to be scrutinized closely, and producing mines will be developed if the lodes are sufficiently rich to justify mining.

The geologic formations present in the region of the lodes include a group consisting of greenstone, tuff, chert, and metamorphic sediments of pre-Triassic age; Triassic conglomerate, tuff, greenstone, limestone, and shale, locally cut by dikes and sills; Mesozoic sediments of post-Triassic age, consisting predominantly of argillite and shale, with some graywacke and conglomerate, all cut by dikes; late Mesozoic or early Tertiary shale, argillite, and conglomerate, with some intrusives; partly consolidated sand, clay, gravel, and lignite beds, of Tertiary age; and widespread deposits of glacial moraine and outwash materials and stream gravel. The general distribution of the rock formations and the location of the mineral deposits are shown on Plate V, which with the following notes is taken from a publication[31] that describes in some detail the conditions in this district at the time of the writer's visit in 1917.

The first mining done in this district resulted in the recovery of a little placer gold in 1909. Since that time the interest of the prospectors has centered on the lodes, some of which contain gold, copper, and antimony in encouraging amounts. The ores are not free milling, however, and the prospective value of the lodes lies in their possibility of yielding a large tonnage of ore of moderate richness rather than small quantities of high-grade ore.

The ore bodies occur in that part of the group of Triassic tuffs and sediments in which calcareous rocks are present, either as lime-

[31] Capps, S. R., Mineral resources of the upper Chulitna region: U. S. Geol. Survey Bull. 692, pp. 207–232, 1919.



GEOLOGIC SKETCH MAP OF THE UPPER CHULITNA REGION.

stone, marble, or limy shale. Furthermore, in the vicinity of the ore bodies there is an unusual amount of igneous material, injected as dikes into the tuff, limestone, and shale. The ore bodies themselves, as exposed in the scanty workings, are not sharply outlined and have not generally a definite veinlike character. They appear to be irregular masses showing in places heavily mineralized rock that fades out into less mineralized country rock in all directions. Scattered specks of sulphides can be found in these rocks over wide areas. The principal metallic minerals recognized include arsenopyrite, pyrite, sphalerite, chalcopyrite, pyrrhotite, stibnite, and galena, and assay returns show the presence of gold. Some small distinct veins cut the ore bodies, and these carry sulphides in a gangue of quartz or calcite, or both, but most of the ore seems to consist of sulphides that have replaced limy rocks, or else it occurs as disseminated sulphides in different types of material, including tuff, chert, limestone, and the dike rocks themselves. The information at hand therefore indicates that as the result of the intrusion of acidic dikes the intruded rocks suffered some contact metamorphism. Mineralized solutions from the igneous mass penetrated the neighboring rocks and replaced certain of the limy beds. The calcareous beds were not alone affected, however, for the sulphide-bearing solutions also penetrated certain tuff and chert beds and replaced parts of these beds with sulphides, but the larger ore bodies, as at present exposed, seem to represent the replacement of calcareous sediments by metallic sulphides. The following descriptions of the several groups of claims are abstracted from the report on this district already cited, written as a result of a visit in 1917. As that report is out of print, fuller descriptions are given here than for other districts concerning which detailed accounts in print are still available.

The Northern Light group of three claims lies on the northeast side of Costello Creek a short distance below the mouth of Camp Creek. The country rock comprises a confused assemblage of volcanic tuff, impure limestone, and shale, cut by dike rocks. The sediments and tuff and even the dike rocks are calcareous. The area of strongest mineralization, which is discolored to a rusty red on the outcrop, is irregular in outline and has a greatest width of about 30 feet. It strikes about N. 65° W. and dips 70° SE. It is apparently the result of the replacement of a limy bed by sulphides and contains veins and bunches of quartz. The ore is said to carry gold and silver in encouraging amounts. The minerals that have been recognized include arsenopyrite, pyrite, chalcopyrite, sphalerite, and a little stibnite.

The Lucrative group, consisting of five claims, lies on Costello Creek near the mouth of Camp Creek. The small amount of de-

velopment work that had been done at the time of visit showed a rusty mineralized vertical stockwork in a mass of intrusive rock. The principal metallic minerals seen consisted of abundant arsenopyrite in bluish banded quartz, with some specks of chalcopyrite.

The Silver King group, consisting of two claims, lies on the northeast side of Colorado Creek about 1½ miles above its mouth. The development work in 1917 consisted solely of open cuts, which failed to penetrate to solid undisturbed rock, so that little could be seen of the relations of the ore deposit. The center of mineralization seemed to be a highly altered dike. The dike probably cuts calcareous sediments, for it contains calcite. There is apparently a large mass of material that contains abundant sulphides, including arsenopyrite, pyrite, chalcopyrite, pyrrhotite, and stibnite, both as massive aggregates and finely disseminated through the country rock. The gold and silver content of this material was not ascertained.

The Riverside group comprises several claims that adjoin West Fork of Chulitna River on its southwest side about a mile above Bryn Mawr Creek. The development work in 1917 consisted of a number of large open cuts and some short tunnels and shafts, all at the base of a steep rock bluff at the edge of the gravel flat of West Fork of Chulitna River. The rocks exposed include steeply dipping green to red tuff, with which are associated pale-pink, green, and blue-gray cherts, locally banded; rusty-gray and white marble; and abundant dikes of medium-grained acidic intrusive rocks. The tuff is hard and dense and ranges in texture from fine grained to very coarse. The marble and chert are less abundant but are visible in several of the open cuts. Tuff, chert, and calcareous beds are all more or less altered by contact metamorphism, as a result of their intimate intrusion by dike rocks. Such data as could be obtained from the meager surface exposures and the workings indicate that here, as at other places in the district, the mineralization consists in the replacement of calcareous materials by quartz and metallic sulphides, introduced by mineralizing solutions that were related to the intruded dike rocks. The ore examined contained abundant sulphides, including arsenopyrite, pyrite, chalcopyrite, galena, and probably sphalerite, inclosed in a quartz gangue, and specks of these sulphides occur without quartz gangue in marble, tuff, and dike rocks. It is reported that average assays taken over a 12-foot zone in marble yielded encouraging amounts of gold and silver.

The Lindfors group includes three claims at the head of Bryn Mawr Creek. No development work had been done here in 1917 other than some open cuts and strippings. The country rock includes tuff, marble, and dike rocks in different stages of alteration, all containing some disseminated sulphides. It is evident that on these claims the mineralization consists in the replacement of

calcareous sediments by quartz and sulphides and the impregnation of different types of country rock with sulphides introduced in connection with the intrusion of acidic dikes. No large body of minable ore had been developed on these claims at the time they were visited.

The Golden Zone group of three claims, at the head of Byrn Mawr Creek, is conspicuous on account of the rusty-red appearance of the hill on which the claims are situated. This hill is composed of a body of acidic rock that is intruded into an assemblage of material including tuff, marble, and shale. The intrusive mass is generally impregnated with scattered specks of sulphides, but locally the mineralization has been more intense and the rock is cut by small veinlets. These claims in 1917 were developed by many open cuts and 221 feet of underground workings. The metallic minerals that have been recognized on this property include arsenopyrite, pyrite, sphalerite, galena, malachite, and probably stibnite. It is reported that assays of the average material removed from the tunnel show several dollars to the ton in gold and silver, and some rather high assays were produced.

The Hector group includes two claims that lie on the Long Creek side of the divide between Long Creek and West Fork of Chulitna River, opposite the head of Bryn Mawr Creek. The development work that had been done in 1917, consisting entirely of shallow open cuts, revealed a country rock that included the metamorphic equivalents of siliceous shale, graywacke, and tuffs, intricately cut by dikes and sills of acidic intrusive rocks. Certain chert bands are highly siliceous, but all the other materials are limy. The ore body as exposed consisted of intimately mixed chalcopyrite and pyrrhotite disseminated through the coarser sediments and the dike rocks. The sulphides have replaced certain beds, but the chert is almost entirely free from mineralization. The suphides range in abundance from scattered specks of chalcopyrite and pyrrhotite to masses of sulphides in which little rock is visible. Assays of the best ore are said to yield 17 per cent of copper, but sufficient work had not been done to determine either the size of the ore body or the average copper content of the ore.

The Ready Cash group lies on the northeast side of Ohio Creek, about 3 miles above the mouth of Christy Creek. The country rock consists of interbedded argillite, graywacke, and greenstone tuffs, all more or less metamorphosed. On this property a large quartz vein 8 to 10 feet wide, showing some rusty coloration and stains of copper carbonate, cuts the sediments. No information was obtained concerning the assay value of the ore at this property.

The North Carolina group of claims lies in the upper basin of Antimony Creek, a small tributary of East Fork of Chulitna River that joins that stream from the east 1 mile above its mouth. The

country rock consists of shale, impure limestone, and graywacke, cut by basic dikes. At one place an antimony lode has been found, consisting of stibnite in a quartz gangue. The only opening on the ore body was caved in at the time of visit, but the dump showed several tons of massive stibnite ore that included both finely granular stibnite and a mixture of granular stibnite with coarse acicular crystals of the same sulphide. Some specimens contain considerable quartz, but in others there was almost no gangue. The workings were insufficient to determine the size or position of the ore body.

Throughout this general region there are many other lode prospects that are not here described individually, either because too little development work had been done to demonstrate the position or relations of an ore body, or because they were not visited. They are of general interest, however, in showing that sulphide minerals are widely distributed in this district, and there is every prospect that producing mines will be opened on some of the lodes in this general vicinity.

As in so many places in the Susitna basin, there are many localities in the headwater region of Chulitna River in which early Tertiary beds containing lignitic coal have been found. Some of those localities are shown on the accompanying geologic map (Pl. I). Although the structure of the coal-bearing beds differs from place to place, the association of beds is everywhere similar, slightly consolidated clay, sand, and gravel being interbedded with lignite. The lignite is of about the same average quality as that mined in the Nenana field. At a number of localities small quantities of this coal have been mined for domestic fuel, and large quantities of it are available, but it is of too low grade for other than local use. The similarity in character, structure, and general appearance between the coal formation of the upper Chulitna basin and that of other parts of the Susitna basin and the Nenana coal field suggests strongly that all these deposits are of about the same age.

VALDEZ CREEK DISTRICT.

The Valdez Creek gold placer district lies at the east margin of the area here under discussion, in the upper reaches of Susitna River. Valdez Creek joins the Susitna from the east some 25 miles below the source of that stream in Susitna Glacier. Gold was first discovered in this district in 1903, and although the area of workable gold placer gravel is small, mining has been carried on vigorously until within the last few years. The conditions in this district in 1910 are described at length by Moffit,[32] and the following notes are abstracted from his report. Most of the placer gold produced has

[32] Moffit, F. H., Headwater regions of Gulkana and Susitna rivers, Alaska: U. S. Geol. Survey Bull. 498, 1912.

been taken from a few claims at the west end of Valdez Creek, just above the place where the canyon opens out into the flats of Susitna River, and from Lucky Gulch. In the vicinity of the mines on Valdez Creek that stream has cut its canyon through the gravel into the slate beneath to a depth of 175 feet and in so doing has intersected an older gravel-filled canyon whose bottom is 60 feet higher than the present creek level. The largest deposits of gold placer gravel were found in that old gravel-filled canyon and in the present creek gravel below the old canyon, indicating that the present stream gravel derived its gold from the erosion of an older, buried placer deposit. The bedrock source of the gold is believed to be certain iron-stained siliceous veins containing pyrite, sphalerite, and galena, which cut Upper Triassic slate. These veins, though known to be gold bearing, have nowhere been found to be minable as gold lodes. The placer deposit in the old buried channel of Valdez Creek is of preglacial origin and is another indication that in the region south of the Alaska Range there were probably many rich placer deposits in preglacial time but that most of these deposits were destroyed by the advancing ice, and the gold was scattered. It is only in such exceptional places as the Valdez Creek district, where the older placer deposits were buried and preserved, or at a few other places where postglacial concentration of gold from glacial deposits or from the bedrock source has occurred, that placers are now found.

On Valdez Creek mining has been most profitable on four or five creek claims, on which the richest gravels have now been mined, and on the Tammany bench claim, which includes the old buried canyon. This old canyon was mined by a tunnel from Valdez Creek, which in 1910 was about 700 feet long. The pay streak is 100 feet or less in width. Most of the gold is found in the lower 5 feet of the gravel filling. A ditch 8,600 feet long was constructed to bring water to this claim for hydraulic mining, and some hydraulic mining has been done, but the remoteness of the district has made operations expensive, and mining has been interrupted from time to time. It is said that much rich ground still remains to be worked.

Aside from the claims on Valdez Creek, described above, the only other mining of consequence in this district has been on Lucky Gulch, about 6 miles east of the main camp on Valdez Creek. The bedrock is the Upper Triassic slate series. The gulch is narrow, and the stream deposits, consisting of angular fragments and slabs of slate, are in places as much as 25 feet thick. The gold in this gulch is exceptionally coarse, nuggets weighing 32 and 52 ounces having been found.

Prospects on White and Rusty creeks give some hope that these streams also contain workable gold placers.

BONNIFIELD REGION.

The Bonnifield region is generally understood as that part of the north slope of the Alaska Range and its outlying foothills that extends eastward from Nenana River to Delta River. Gold was first discovered in this region in 1903, and since that time placer mining has been carried on continuously, and the gold production, though never large, has been steady. Gold lode prospects have received some attention for more than 15 years, and within the last half dozen years a number of lodes containing gold, bismuth, and antimony have been staked and some development work has been done on them, but no actual mining has so far been done on metal-bearing lodes. The Bonnifield region was visited by Capps[33] in 1910.

In 1916 parts of the Nenana coal field were studied in detail by Martin,[34] the lode prospects of the region near the Nenana coal field by Overbeck,[35] and the gold placers of the same area by Maddren.[36] The following notes are abstracted from these reports, to which the reader is referred for fuller descriptions of the individual mines.

GOLD DEPOSITS.

The localities in which placer gold in paying quantities has been found in this region all lie in the foothill belt between the Tanana Flats and the high schist range to the south. The present streams derived the gold from a variety of sources, chief of which is a heavy deposit of ancient high gravel that is widely distributed in this region and is known to contain some gold at many places. At one or two places, however, the gold of the present streams seems to have come directly from a bedrock source in lodes that have been eroded by the streams in postglacial time. Almost all the gold placer deposits in the Bonnifield region are either in the valleys of relatively small streams that escaped invasion by glacial ice during the last great ice advance or in postglacial valleys cut into the Nenana gravel and bedrock since the glaciers retreated. Attempts have been made at many places to mine the Nenana gravel in a small way, and one large hydraulic plant was installed for this purpose on Gold King Creek, but none of these operations have been financially successful, for apparently the gold in the Nenana gravel is too widely distributed and insufficiently concentrated to justify mining unless it has been reconcentrated by the present streams.

According to present reports the most extensive mining operations in 1922 were on Moose Creek, a tributary of Nenana River, and on

[33] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, 1912.

[34] Martin, G. C., The Nenana coal fields, Alaska: U. S. Geol. Survey Bull. 664, 1919.

[35] Overbeck, R. M., Lode deposits near the Nenana coal field: U. S. Geol. Survey Bull. 662, pp. 357–362, 1917.

[36] Maddren, A. G., Gold placers near the Nenana coal field: Idem, pp. 363–402.

Totatlanika River and its tributaries. The placer-gold output of the Bonnifield region in 1922 was about $10,000, and the total output from 1903 to 1922 has been about $285,000.

There has been no lode mining of metals in the Bonnifield region, but there are a number of lode prospects that offer some promise. These include the gold-arsenopyrite-bismuth lodes on Moose and Eva creeks and a few gold quartz lodes on McCuen Gulch and in the basin of Wood River. The country rock of the lode prospects on Moose and Eva creeks and in the Totatlanika basin is a dark carbonaceous phase of the Totatlanika schist which has been cut by igneous dikes. Too little work has yet been done to outline the ore bodies, or to determine whether any of them are likely to develop into mines.

NENANA COAL FIELD.

One of the most valuable mineral resources in the region tributary to the Alaska Railroad is the coal of the Nenana field, which includes the coal-bearing areas that lie in or near the basin of Nenana River. In that field occur the thickest sections of the coal-bearing series that have been examined and the largest amount of minable coal, but similar coal-bearing beds are known to occur at intervals along the entire northern flank of the Alaska Range, from Muldrow Glacier on the west to the international boundary on the east. Naturally the availability of transportation and the grade of the coal will determine the localities that will be first developed, and therefore the favorable location of the series of thick coal beds in the valleys of Healy and Hoseanna creeks, directly adjoining the new railroad, will hasten their devolopment, whereas many other coal beds situated at more remote points will long remain undeveloped or at best will be opened to supply only local needs.

As a detailed examination was made by Martin[37] of the surveyed coal lands just east of Nenana River, only a general statement concerning this field will be given here. The coal, which is a lignite of very fair grade, occurs in a series of Tertiary sediments consisting of slightly consolidated sand, clay, and gravel, which reaches a known thickness of 1,200 to 1,500 feet. The coal-bearing beds rest unconformably upon pre-Cambrian or Paleozoic schist and igneous rocks and are overlain unconformably by later Tertiary or Quaternary gravel, 1,500 or 2,000 feet thick. The structure of the coal beds is fairly simple. The individual coal areas consist of shallow and gently warped basins in which the beds are locally folded or faulted against the older rocks that separate the basins. The dips are in general not greater than 10° or 15°, though there are local

[37] Martin, G. C., The Nenana coal field, Alaska: U. S. Geol. Survey Bull. 664, 1919.

zones in which the dip is steeper, as well as broad areas in which the rocks lie nearly flat. No intrusive rocks are known to cut the coal measures in the areas near Nenana River, though farther west, in the Kantishna region, similar coal-bearing beds contain abundant fragments of igneous material and are believed to be cut by dikes.

The coal of the Nenana field occurs in many beds of different thickness, the thickest measuring perhaps 30 to 45 feet, though locally some beds have been thickened by deformation to considerably more than that. The lignite beds are distributed rather uniformly through the coal measures, and there are at least twelve coal beds of workable thickness, and six or more measure over 20 feet. A single section measured on Healy Creek showed a total thickness of 230 feet of coal in 23 beds, of which seven beds contain 174 feet. Analyses show that the coal is a lignite of good grade, of about the same quality as that of Cook Inlet. It has been estimated that the Nenana coal field contains reserves of more than 9,000,000,000 tons.

Prospecting and mining of coal in the Nenana field has been greatly stimulated since railroad transportation has been available. Several coal beds along Nenana River and on Hoseanna and Healy creeks have been opened, and a considerable tonnage of coal has been mined for the railroad and for general use in Nenana and the Fairbanks district. Already the cost of fuel for domestic purposes, for power, and for steam raising in the Fairbanks placer mines, where it is necessary to thaw the frozen ground, has been reduced. This coal will continue to furnish a valuable and much needed fuel supply for a large area in interior Alaska, but its market is likely to continue to be limited to that area, as it is of too low grade and too fragile to stand shipment outside of Alaska in competition with higher-grade coals and oil.

In the spring of 1923 vigorous development was begun on a coal bed that crops out just west of the railroad, at mile 341, near Yanert station. The occurrence of coal at this locality is of especial interest, for the coal bed lies in the Cantwell formation, of early Tertiary age, and is the first workable coal bed that has been found in that formation. During the summer of 1923 mining developments demonstrated that the coal bed contains from 5 to 6 feet of workable coal lying interbedded with the steeply dipping shale, sandstone, and conglomerate of the Cantwell formation and closely paralleled on its hanging wall by a thick sill of intrusive rock. The coal is a bright, clean, noncoking bituminous coal and is apparently of higher quality than any of the other coals of the Nenana field. In appearance and in analysis it compares favorably with the better coal of the Matanuska Valley. The discovery of good bituminous coal in the Cantwell formation opens up interesting possibilities,

for that formation is of widespread distribution in the Alaska Range, and it may contain workable coal beds elsewhere. Mining developments on coal in the Cantwell formation are, however, not yet far enough advanced to determine whether the quality of the coal has been affected favorably or unfavorably by the near-by intrusive sill.

KANTISHNA DISTRICT.

The Kantishna mining district is about 60 miles west of the railroad on the north side of the Alaska Range, about 30 miles north of Mount McKinley. Gold-placer mining has been conducted there continuously each summer since 1905, and for the last ten years or so lode mining and prospecting has attracted increasing attention. Although the yield of placer gold has never been large, it has been steady. The value of the gold produced in 1922 was about $32,000, and the total value of the placer output of this camp from 1903 to 1922 is $509,000.

The geology and the location of the mineral deposits of this district are shown on the accompanying map (Pl. VI). The bedrock in the vicinity of the placer mines is the Birch Creek schist, which is cut by some acidic intrusive bodies, and the placer gold is believed to have been derived by the erosion of gold-bearing quartz veins that cut the schist. Some of these veins also carry rich silver-bearing galena, and others have large deposits of stibnite. In 1921 the known mineralized area in the Kantishna district was extended southward nearly 20 miles by the discovery on Copper Mountain, just west of Muldrow Glacier, of sulphide veins that occur in quartzite, limestone, and slate cut by granodiorite. These veins carry gold, silver, and copper.

The geology and mineral resources of the Kantishna district were studied by Capps[38] in 1916, and the reader is referred to his report for the details of mining developments up to that time. There is given here only a brief summary of the mining activities in the district and of developments since 1916.

GOLD PLACERS.

For many years after the discovery of gold in the Kantishna district in 1915 the interest of miners and prospectors was confined to the gold placer gravels. Mining was done on many streams that head in the Kantishna Hills, but the chief activity has always centered on Moose Creek and its tributaries, Glen, Eureka, and Friday creeks, and on Glacier and Caribou creeks. On all these streams most of the gold produced has been obtained from the creek

[38] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, 1919.

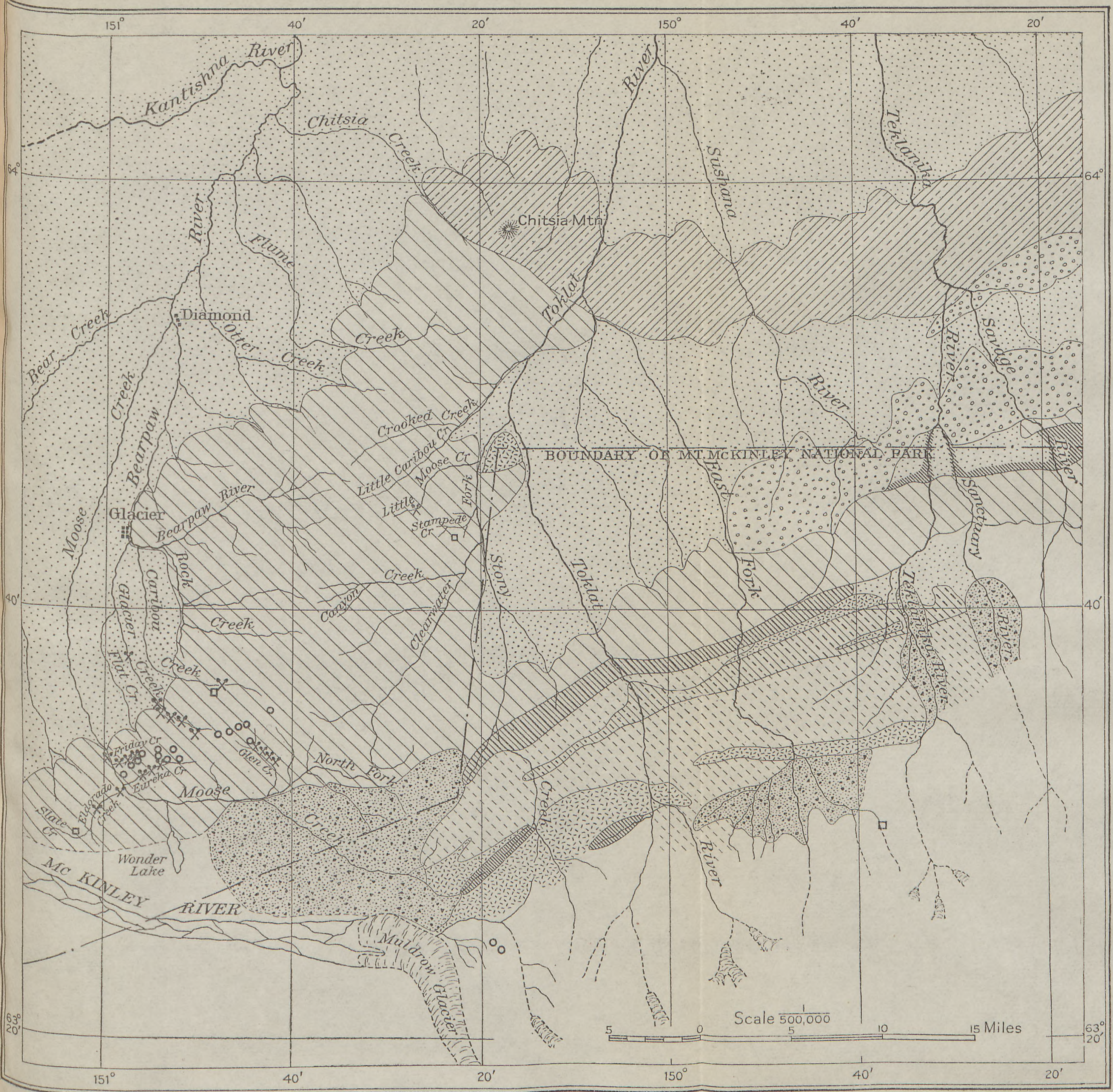
gravel, which is generally of moderate thickness and lies on a schist bedrock. The gold in this district is coarse, nuggets worth as much as $900 having been found. Eureka and Friday creeks in particular are noted for the rough, unworn character of their placer gold, which has evidently traveled only a short distance from its bedrock source. On the larger streams, notably Moose, Glacier, and Caribou creeks, there are extensive deposits of bench gravel that are known to carry gold in encouraging amounts and are susceptible of large-scale hydraulic mining. Moose Creek has also much ground that has been prospected for dredging. In 1922 two large hydraulic mines were opened in this district. One, the property of the Kantishna Hydraulic Mining Co., is on Moose Creek, the ground extending from a point near the mouth of Eureka Creek for about 3 miles downstream. Water is procured from Wonder Lake and is brought to the mine through a ditch and a steel pipe. The placer gravel is underlain by a false bedrock of sticky blue clay at a depth of 6 to 10 feet. The depth to true bedrock is not known. The richest ground is found near the false bedrock, although some gold is distributed throughout the gravel. Hydraulic giants with nozzles ranging from 3 to 4 inches in diameter are used. Seven men were employed in 1922, and a large amount of gravel was sluiced.

A hydraulic mine was opened in 1922 on ground said to include all the creek gravel along Caribou Creek for several miles and a large number of bench claims. Mining was done on the gravel of Caribou Creek about 2 miles below Last Chance, the water being taken from Caribou Creek by ditch and steel pipe. A large area of bedrock is said to have been uncovered.

The installation of large-scale hydraulic-mining operations in the Kantishna district will, if successful, greatly increase the placer output from this camp and encourage the thorough prospecting of other areas which are known to be gold bearing but in which the gold content of the gravel is too low to support mining on a small scale.

GOLD AND SILVER LODES.

For the last 10 years it has been known that this district contains quartz vein deposits that carry a promising content of gold and silver. Most of these lodes lie within a small area along the high ridge of the Kantishna Hills, between the big bend of Moose Creek and Spruce Peak, an area underlain by the Birch Creek schist, cut by a few granitic intrusive masses. The veins are fissure veins that cut across the foliation of the schist, are undeformed, and were therefore deposited after the last period of deformation that affected the schist. They are probably genetically related to the granitic intrusive rocks that cut the schists and that are abundant a few miles south of this



EXPLANATION

SEDIMENTARY ROCKS

QUATERNARY — Pleistocene and Recent.

Gravel

Glacial morainal deposits

TERTIARY

Nenana gravel (Old tilted gravels)

Coal-bearing beds (Sand, shale, gravel, and lignite)

Cantwell formation (Shale, sandstone, and conglomerate)

SILURIAN OR DEVONIAN(?)

Totatlanika schist (Schist and gneiss; containing other metamorphosed sediments)

Tonzona group (Black slate and argillite, some phyllite and schist)

ORDOVICIAN(?)

Tatina group (Black slate and argillite, massive graywacke, and some interbedded limestone and chert)

PRE-ORDOVICIAN

Birch Creek schist (Micaceous and quartzitic schists)

IGNEOUS ROCKS

Dikes, lava flows, and intrusive masses

Gold placer mine

Gold-silver lode prospect

Antimony lode prospect

GEOLOGIC SKETCH MAP OF THE KANTISHNA DISTRICT.

area. Many of these veins have been prospected by open cuts, tunnels, and shafts, and the quartz has in places been shown to carry a high content of free gold and silver-bearing galena. No mining has been done on veins whose chief value is in gold, but in 1919 a silver-bearing galena deposit, lying between Eureka and Friday creeks, was opened up, and about 1,100 tons of hand-picked ore has been shipped. This ore yielded about 140 ounces of silver and $3.25 in gold to the ton, also some lead and copper. It is believed that some of the richer gold-silver quartz veins will be found rich enough to justify mining, as exceptionally high assays in gold and silver have been obtained from some of them.

In 1921 sulphide-bearing lodes carrying gold and silver were discovered on the south flank of the Alaska Range some 20 miles southeast of Eureka Creek, in what is called the Copper Mountain district.[39] This district lies just east of Muldrow Glacier. Granodiorite is the prevailing country rock and is found in large areas and as dikes that cut quartzite, limestone, and slate that are probably of Paleozoic age. The ore-bearing zone has been traced for about 2 miles and is characterized by abundant sulphide minerals concentrated into ore bodies. Some of these bodies have definite walls; in others the ore grades into the country rock. They occur chiefly in the quartzite, but some are in the granodiorite and others at the contact between the two. The ore consists chiefly of galena, chalcopyrite, zinc blende, pyrite, and bornite, with galena predominating. The gangue is quartz and country rock, chiefly quartzite. Grab samples have yielded as much as 270 ounces of silver and $8 in gold to the ton and from 1 to 8.8 per cent of copper. Up to July, 1922, little work had been done on these claims, and their value could not be predicted, but the surface exposure fully justified careful prospecting.

ANTIMONY LODES.

A number of lodes in the Kantishna district contain considerable deposits of stibnite, the antimony trisulphide, and mining or development work has been done on at least three lodes, with the purpose of shipping the ore for its antimony content. Genetically the antimony lodes are related to the gold-silver lodes already described, and the veins have the same association of minerals, but in the antimony lodes stibnite occurs in large masses containing only small amounts of gold and silver, whereas in the gold-silver lodes antimony, although occasionally recognized, is a minor constituent.

Although the presence of considerable masses of stibnite in veins in this district has been known since the first years of mining, it

[39] Brooks, A. H., The Alaskan mining industry in 1921: U. S. Geol. Survey Bull. 739, pp. 35–37, 1922.

was not until the demand for antimony during the World War raised the price of that metal to many times its pre-war value that any attempt was made to exploit these veins. In 1915 the Taylor mine, on Slate Creek, was opened, and by 1916 about 125 tons of hand-picked ore had been mined and preparations were made to ship the ore out by way of Kantishna River to the Tanana and thence to Seattle. Before the ore was shipped, however, the price of antimony declined so that this ore could not meet the high cost of transportation, and it was never marketed. In the Taylor mine the stibnite formed an ore body along a well-defined fissure in the Birch Creek schist. The ore body had a maximum width of 15 feet and constituted a reticulated stockwork of quartz and stibnite with irregular bunches and horses of decomposed clayey schist, all much broken and confused. The stibnite occurred in veinlets and veins of almost pure stibnite and in irregular lenses and bunches.

The only other antimony lode on which any mining has been attempted is on Stampede Creek, a tributary of Clearwater Fork of Toklat River from the southwest. There a large open cut, excavated in 1916, disclosed a large body of nearly pure stibnite, apparently at least 12 feet thick. About 40 or 50 tons of selected stibnite almost entirely free from gangue or impurities had been mined and stacked, but none of this was ever shipped. Too little work had been done at the time of examination to disclose the size or relations of this ore body.

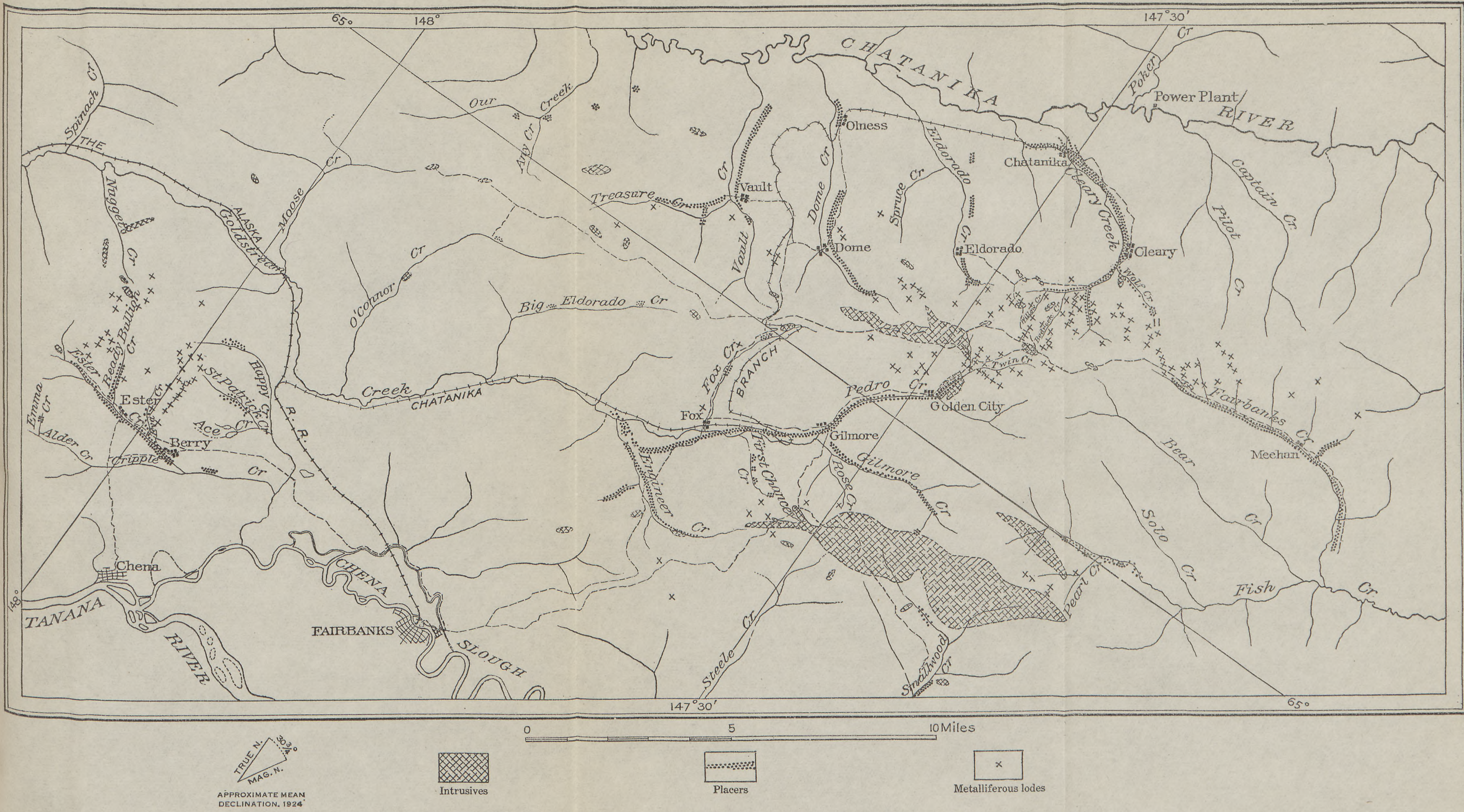
A third antimony lode, on upper Caribou Creek, was prospected in 1906 by two shafts 30 and 40 feet deep. These shafts showed a mixture of quartz and stibnite in a vein cutting hornblende schist. This ore body, as developed by the shafts, does not appear to be as large as either of the two lodes already described. Assays showed the ore from this place to carry from a fraction of an ounce to 4 ounces of silver to the ton. No attempt has been made to mine this lode.

FAIRBANKS DISTRICT.

GOLD PLACERS.

The Fairbanks mining district lies on the north side of Tanana River, in the extreme northwest corner of the area here considered. The town of Fairbanks is the inland terminus of the Alaska Railroad. From the beginning of placer mining in 1903 to 1922 this district has produced over $72,037,000 worth of gold—$71,973,000 in placer gold and $367,000 in lode gold—also nearly $377,000 worth of silver, all recovered as an alloy with the gold. No mining for silver as the chief metal produced has been done in this district.

The geology of the Fairbanks district is shown on the accompanying map (Pl. VII). This district has been visited by many geol-



MAP SHOWING POSITION OF LODE MINES AND PROSPECTS AND PLACER GRAVELS IN THE FAIRBANKS DISTRICT.

ogists of the Geological Survey, and descriptions of the mining developments year by year have been published in the annual reports on the mineral resources of Alaska. The most complete report on the geology and mineral resources of the Fairbanks district is that by Prindle, Katz, and Smith,[40] which describes in detail the mining developments that had taken place up to 1912. The reader is referred to that report for general information about the Fairbanks quadrangle. The present brief account is summarized from that report and from the various other Geological Survey publications.

The geology of the Fairbanks district may be stated in very simple terms. The prevailing bedrock is a schist of sedimentary origin known as the Birch Creek schist, cut by moderately large to small masses and dikes of granitic intrusive rock. Most of these intrusive masses are too small to be shown on the accompanying geologic map (Pl. I), but many are shown on Plate VII. There is believed to be a genetic relation between these acidic intrusive rocks and the gold-bearing quartz veins in the schist, the erosion of which has supplied the gold to the placer deposits. The erosional history of this district has been complex, a period of stream erosion in which deep broad valleys were cut into the schist and intrusive rocks having been followed in late geologic time by a period of more sluggish drainage, during which thick deposits of stream gravel, muck, and ice filled these valleys to a depth of several hundred feet. This filling was once much deeper than it is now, as shown by elevated terraces of silt and gravel, but in their lower courses all the major streams still flow on the surface of a deep valley filling, the bedrock lying as much as 100, 200, or even 300 feet below the present stream plain. A fuller explanation of the causes for this deep burial of the rock valley floors is given in another section of this report.

The main concentration of placer gold in the Fairbanks district took place before the old valleys were filled with their present great accumulations of material. This material is now generally frozen solid. To prospect and mine these old buried pay streaks, which usually are found on or near bedrock, it is necessary to sink shafts through the frozen valley filling, and if paying ground is found on bedrock, then the gold-bearing gravel must be thawed and brought to the surface, and the gold extracted by the ordinary methods of washing the gravel through sluice boxes. A large part of the gold recovered in this district has been mined in this way. In other places, however, principally near the heads of the streams, where the altitude of the bedrock floor is greater than the height to which the valleys have been filled, the bedrock approaches closer to the surface, the streams flow over a gravel filling of only moderate depth,

[40] Prindle, L. M., Katz, F. J., and Smith, P. S., The Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull, 525, 1913.

and open-cut methods of mining, by steam scraper, dredge, hydraulic, or pick and shovel, are employed. Large areas of gravel of moderate gold content remain to be worked by mechanical and to a lesser extent by hydraulic methods, but most of the rich, shallow gravel has long ago been worked out.

The list of producing creeks in this district changes from time to time, as some are mined out and others become productive through new discoveries. The largest producing streams to date are, in the order of their production, Cleary, Goldstream, Dome, Fairbanks, Ester, Vault, and Little Eldorado creeks.

The placer gravel in any stream basin consists of pebbles and boulders of the rocks that crop out in that basin. In this district it includes quartzite, schist, and igneous rocks. The richest gravel almost invariably occurs immediately above the bedrock, and the gravel having sufficient gold content to justify mining ranges in thickness from a few inches to about 10 feet and averages about 6 feet. The pay streak varies greatly in width but throughout the district has an average width of about 200 feet. The value per cubic yard of the ground mined has greatly decreased since the installation of dredges and hydraulic mines on a large scale, for these mines are able to handle profitably gravel of much lower grade than can be worked by underground mining. It is estimated that the average gold content of the ground mined in 1908 was $5.60 to the cubic yard. By 1922 the average value had fallen to $1.34 to the cubic yard. These figures indicate the trend of mining in the district, and it is to be expected that the future will see a still further decrease in the gold tenor of the ground mined, as the richer but smaller placer deposits are exhausted and large-scale mechanical operations are extended. The great bulk of the gold recovered is composed of flattish pieces a quarter of an inch in maximum diameter; of granular pieces, some of which are minute; and of considerable very fine gold. The proportion of nuggets is small; those worth a few dollars are common, and some ranging from $100 to $529 have been recovered. The gold ranges in value from about $16 to over $19 an ounce. In 1922 the producing creeks and their tributaries were, in the order of their production, Goldstream, Fairbanks, Dome, Little Eldorado, Cleary, Ester, and Vault.

GOLD LODES.

Prospecting in the endeavor to find the lodes from which the placer gold of the stream beds was derived has attracted the attention of many men since the early years of placer mining in the Fairbanks district. By 1910 many lodes had been located, and a few of them were opened and some mining was done that year. From

1912 to 1915 great activity was displayed in developing lode mines, and during those years the annual production from such mines ranged from over $200,000 to nearly $400,000 in gold and silver. By 1916,[41] however, the cost of supplies, power, and labor had so greatly increased that the production fell off sharply, and it remained below $50,000 each year until 1922, when $54,000 worth of lode gold was produced. This increase is probably attributable to the opening of railroad communication with the Nenana coal field. With the cheaper power that will be possible by using Nenana coal for raising steam, the output of the lode mines will doubtless continue to increase. In 1922 active mining was done on five properties, and prospecting and development work on a number of others.

The lodes, most of which are valuable chiefly for their content of free gold, are quartz veins in the schist, and the age of the mineralization is not well known. Some of the veins cut the schist; others lie parallel to it. There has been considerable local faulting, which in places makes it difficult to follow the ore bodies. Quartz is by far the most abundant vein mineral, but a little orthoclase and some sericite are found. The metallic minerals so far recognized in the veins include pyrite, limonite, stibnite, arsenopyrite, galena, bismuthinite, scheelite, sphalerite, and gold. Cassiterite, wolframite, and bismuth have been found in the stream gravel and must occur in the bedrock somewhere within the district. The gold-bearing veins are generally narrow, ranging from a few inches to 3 or 4 feet in width, and pinch and swell in thickness both horizontally and vertically. The gold is unequally distributed in the quartz, rich shoots of ore being succeeded by relatively lean ore. More than a dozen mines in the district have at one time or another been equipped with ore-crushing machinery, and others have sent ore to custom mills for reduction. The present outlook for lode mining indicates many small mines working relatively rich ore rather than large mines operating on ore of moderate to low grade. For a more detailed account of lode-mining developments in 1922 the reader is referred to a fuller account by Davis.[42]

ANTIMONY LODES.

As a result of the war demand for antimony in 1916 and the consequent high prices offered, several mines were operated in the Fairbanks district to produce antimony ore from stibnite-bearing veins, and about 4,000 tons of ore was shipped. Since 1916 none of these mines have been operated. The ore occurs in quartz veins in the

---

[41] Mertie, J. B., jr., Lode mining in the Fairbanks district: U. S. Geol. Survey Bull. 662, pp. 403, 424, 1918.

[42] Davis, J. A., in Stewart, B. D., Annual report of the mine inspector to the Governor of Alaska, 1922, pp. 88–113, 1923.

Birch Creek schist, in genetic relation to granitic intrusive rocks. The metallic minerals in the antimony veins are the same as in the gold quartz veins, the principal difference being in the greater abundance of stibnite and the smaller gold content of the veins that have been mined for antimony. It is not likely that the antimony mines of this district will again be actively exploited unless there is some great increase in the price of antimony, and such an increase can not be foreseen.

TUNGSTEN LODES.

During the war years 1915 to 1917 tungsten, like antimony, was in great demand and commanded a high price. It had been known for many years that tungsten-bearing minerals occur in the Fairbanks district, and under the stimulus of high prices prospecting for tungsten lodes was vigorous, and in 1915 and 1916 workable lodes were discovered and mining begun. The principal mining was done on the divide at the head of Gilmore Creek, though promising prospects were also found on the divide between First Chance and Steele creeks. At the principal producing properties, the Tungsten and Scheelite claims, at the head of Gilmore Creek, the country rock consists largely of crystalline limestone that is extensively silicated at certain horizons; this silicated limestone contains mineralized zones or ore shoots that carry the tungsten mineral scheelite in amounts that constituted workable ore at the prices obtainable in 1915. The scheelite is disseminated through the country rock and also occurs in pegmatite. There are two bodies of porphyritic granite within two-thirds of a mile of the ore deposits, and the presence of tungsten-bearing pegmatite plainly indicates the genetic relation of the scheelite to the granitic intrusives.

On the Tanana group of claims, at the head of First Chance Creek, a number of scheelite-bearing lodes, in quartzite schist country rock, were prospected, and some mining was done. The ore occurs in mineralized zones 3 to 8 feet thick, lying parallel to the major structure of the schist or at its contact with granitic intrusive bodies. The scheelite is in part disseminated in the country rock, in part in gold and scheelite bearing quartz veins and veinlets and as scheelite-bearing pegmatite.

On the Black Joe and Mizpah claims, on Fairbanks Creek, scheelite occurs in a gold-bearing quartz vein in quartzite schist; the gold and the scheelite, however, are found in different parts of the vein.

On at least half a dozen other claims in the district scheelite lodes have been discovered with geologic relations similar to those in the lodes already described. Since 1917 all mining on tungsten lodes in the Fairbanks district has ceased, as the decreased price for the metal has made mining unprofitable.

HOT SPRINGS DISTRICT.

Gold placer mining began in the Hot Springs district in 1902 and has been continued each year since. The gold yield from this district has aggregated $6,268,000 up to 1922 and in seven separate years reached a value of $400,000 or more, but in 1921, as a result of the high cost of mining, the output fell to $35,000. In 1922 $55,000 worth of gold was produced, and a further increase in output is likely to follow the cheapening of mining operations that will be possible, now that railroad transportation from the coast to Tanana River is available.

The most complete report on the geology and mining of the Hot Springs district is that by Eakin.[43] The following notes are abstracted from that report and from various other later publications.

All the gold mined in this district has been taken from placer deposits. The bedrock source of the gold is believed to be in the slate, quartzite, and schist of the Tonzona group, probably of Silurian or Lower Devonian age. This series of altered sediments is cut by abundant quartz veins, and although none of these veins have yet proved rich enough to make lode mining profitable, many of them are known to contain gold. There is some evidence also that gold occurs locally in the slate and quartzite without quartz gangue and in hematite bodies near Hot Springs and on Roughtop Mountain. No doubt all these sources have contributed gold to form the placer deposits. The placer gravel of Sullivan Creek also carries considerable amounts of the tin oxide, cassiterite. The abundance of cassiterite in the gravel deposits varies with their richness in gold, the placers that contain the most gold also carrying the highest proportion of cassiterite. The district has produced several hundred tons of tin ore, although the tin saved has been a by-product of gold mining. In fact, many operators consider the tin to be a nuisance, its presence causing a greater increase in the cost of separating the gold than its market value. The source of the tin is not known, and no tin-bearing lodes have yet been found.

The principal mining activities of the Hot Springs district are centered around Tofty, on Sullivan Creek; on American Creek; and in the basin of Baker Creek, which lies just north of the area covered by Plate I and is therefore outside the field of this discussion.

The gold placers in the headward portion of the Patterson Creek basin and on American and Woodchopper creeks are of especial interest in that in many places they have no evident relation to the present streams. Much of the placer gravel mined occurs as benches

---

[43] Eakin, H. M., Reconnaissance of the Rampart quadrangle, Alaska: U. S. Geol. Survey Bull. 535, 1913.

on gently sloping hillsides, where the well-rounded gold-bearing gravel is overlain by silt or by black muck and silt. Much of the mining has been done by drifting, and the depth to the pay streak was in places as much as 70 feet.

Recent operations near Tofty include hydraulic mining after the ground had been thawed by the cold-water method, and this has decreased mining costs in an encouraging way. The lack of sufficient water for extensive mining is a serious handicap.

On American Creek mining has recently been done by means of a steam scraper in ground that averaged about 9 or 10 feet in depth to bedrock before the surface muck was removed by ground sluicing. Some drift mining is still carried on there.

THE COLD BAY-CHIGNIK DISTRICT.

By W. R. Smith and Arthur A. Baker.

INTRODUCTION.

LOCATION AND AREA.

The area described in this report lies on the southeast side of the Alaska Peninsula west of Kodiak Island and extends from a point 15 miles northeast of Cold Bay for 160 miles southwest along the peninsula to the northeast side of Chignik Bay. This area lies between meridians 155° and 158° west and parallels 56° and 58° north. The northeastern portion of the area includes a part of the Cold Bay district, which has already been described by Capps.[1] Cold Bay lies on the southeast side of the Alaska Peninsula at longitude 155° 30′ west and latitude 57° 45′ north. The mapping by the Geological Survey in 1922 is a continuation of the mapping begun by S. R. Capps and R. K. Lynt in 1921. The geographic boundaries of the area of which a geologic map has now been made are, in the northeastern part, Becharof and Ugashik lakes on the west, the Kejulik Mountains on the north, and the coastal mountains from a point near Mount Katmai to Cold Bay on the east. Between Cold Bay and the southwest end of Wide Bay the mapping has been carried to the shores of Shelikof Strait. Between Wide Bay and Amber Bay the area mapped is about 18 miles wide and lies west of the main crest of the Pacific coastal range and east of a broad expanse of low land bordering Bristol Bay. From Amber Bay to Chignik Bay the mapping has been carried to the coast. The total area mapped geologically in 1922, lying between the head of the Kejulik Valley and the northeast end of Chignik Bay, includes about 2,500 square miles.

PREVIOUS SURVEYS.

The first extensive charting of the coast line of the peninsula was begun in 1827 by Capt. F. P. Lutke, who was sent out by the authorities at St. Petersburg to make a careful survey of the north coast.

[1] Capps, S. R., The Cold Bay district: U. S. Geol. Survey Bull. 739, p. 77, 1922.

Several years later the south coast was mapped by Ensign Vasilief. Although numerous surveys of parts of the Alaska Peninsula have been made since Alaska passed into the hand of the United States, there remain stretches of many miles of coast line which have not been charted since the work of Lutke and Vasilief and for all existing maps of which their charts are still the basis.

The occurrence of petroleum in sedimentary rocks of the Alaska Peninsula has been known for over half a century, but until the present investigation only a small part of the peninsula had been mapped either geologically or topographically. The earliest references to the occurrence of petroleum were made in 1869 by Davidson [2] and Dall,[3] who reported the presence of a seepage near Katmai Bay, northeast of Cold Bay. A bibliography of publications referring to the occurrence of petroleum in Alaska, compiled by Martin,[4] was published in 1921. The only additional publications that have appeared since then are the report on the Cold Bay district by Capps [5] and that on Iniskin Bay by Moffit.[6]

Previous surveys in the Cold Bay region have been confined largely to hasty reconnaissance trips along the coast and into the more accessible parts of the region. Several expeditions visited Cold Bay to study and report on the thick stratigraphic and structural sections exposed there, and the general geology of the country adjacent to the shores of the bay has been known for many years. During the oil excitement in 1903–4, when the wells were drilled near Cold Bay, G. C. Martin visited the well sites, and a report of his findings has appeared in several publications. In 1921 S. R. Capps made a reconnaissance survey of the country between Wide Bay and Cold Bay, which supplied more accurate information on that area. The territory immediately north of Cold Bay and southwest of Wide Bay had remained virtually unexplored, as they had been visited only by a few trappers and prospectors. Within the last two years many oil claims have been staked in the Kejulik River valley and near Aniakchak Bay.

The country near Mount Peulik has been somewhat better known than that north of Cold Bay and southwest of Wide Bay, but until work was done there by Capps in 1921 no authentic geologic knowledge of it was available. Many prospectors were attracted to the so-called "west field," lying southeast of Mount Peulik, during the oil excitement in 1903–4, but no systematic mapping was undertaken and no accurate information was published. Private examinations have

---

[2] Davidson, George, Coast Pilot of Alaska, 1869, p. 36.

[3] Dall, W. H., idem, p. 199.

[4] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, pp. 75–80, 1921.

[5] Capps, S. R., The Cold Bay district: U. S. Geol. Survey Bull. 739, pp. 77–116, 1922.

[6] Moffit, F. H., The Iniskin Bay district: Idem., pp. 117–135.

been made at different times with the idea of developing the area if it held sufficient promise of oil production. In 1918 a geologist made an examination for a group of claimants, and in 1921–22 geologists reported on this area for several different oil companies. Surveys other than geologic have been carried on by the United States General Land Office, which had parties in the field in 1920–21 and west of Kujulik Bay in 1921–22, establishing land lines to which claim surveys could be accurately tied. In 1921 a reconnaissance topographic map of the region between Cold Bay and Portage Bay was made by members of the United States Geological Survey. The survey of oil-claim boundaries has been carried on so energetically that the vast network of claims has practically all been surveyed.

A geologic and topographic reconnaissance map of the country bordering Chignik Bay as well as the Herendeen Bay and Unga Island region was made by Atwood and Eakin in 1908, and a report on the work was published the following year,[7] and a fuller report containing geologic and topographic maps in 1911.[8] The coal resources of these districts have been mentioned in several other publications. The region lying between Wide and Chignik bays had not been examined by members of the United States Geological Survey before the summer of 1922. Some of the chief physiographic features, such as Mount Chiginagak and the larger lakes and streams, were named or indicated on the Russian maps, but otherwise the greater part of the interior was unknown. The coast and the south side of the mountain range between Wide Bay and Amber Bay has not been mapped since the acquisition of Alaska by the United States.

PRESENT INVESTIGATION.

In the spring of 1922 two combined geologic and topographic parties were organized, one in charge of R. H. Sargent with W. R. Smith attached as geologist and the other in charge of R. K. Lynt with A. A. Baker as geologist. Each party consisted of 6 men and 10 pack horses. The parties sailed from Seattle June 4 and landed at Portage Bay June 15. Mr. Sargent's party continued westward, and Mr. Lynt's party made a circuit through the country surrounding Mount Peulik and then tied on to previous work at Cold Bay and carried the survey northeastward into the Kejulik Valley.

Mr. Sargent's party made a topographic and geologic reconnaissance survey for about 90 miles parallel to the west side of the coast range southwest of Wide Bay and arrived at Chignik in September. The season's work resulted in a topographic map of an area of about

[7] Atwood, W. W., Mineral resources of southwestern Alaska: U. S. Geol. Survey Bull. 379, pp. 108–152, 1909.

[8] Atwood, W. W., Geology and mineral resources of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, 1922.

3,000 square miles on a scale of 1:180,000 and a geologic examination of an area of about 2,000 square miles. Mr. Lynt's party made a topographic map covering an area of about 1,200 square miles on a scale of 1:180,000, largely by photo-topographic methods, and a reconnaissance geologic map of an area of about 500 square miles. The work of the two parties thus resulted in a topographic map of about 4,200 square miles and a geologic map of about 2,500 square miles. (See Pl. VIII.)

The vicinity of Cold Bay was the scene of much activity during the summer of 1922, as it had been in 1921. Besides the United States Geological Survey parties, several geologists, representing at least three different oil companies, were making examinations of the possible oil-pool locations. One of the companies, which later imported drilling equipment, had several men engaged in work preliminary to drilling, such as choosing a harbor, selecting one of several possible routes for a road, and deciding on a well site. Two different surveyors had parties making boundary surveys of oil claims.

Thanks are due to R. H. Sargent and R. K. Lynt for furnishing base maps in the field and for unfailing assistance in furthering the writers' investigations. To Messrs. Adolf Van Hammel, Charles Weideman, and C. W. Olsen acknowledgment is due for supplying Mr. Sargent's party with several essential articles of food at Aniakchak Bay. Obligation is also acknowledged to the officials of the Northwestern Canneries Co. for the use of a boat at Chignik Bay.

GEOGRAPHY.

TOPOGRAPHY.

The general geographic features of the Alaska Peninsula have been so well described in at least two reports [9] that only a brief summary will be given here. The peninsula is a wedge-shaped land mass extending from northeast to southwest and tapering toward the southwest end. It is about 550 miles long and at its northeast or landward end 100 miles wide. The coast line is very irregular, having many indentations and large bays which in a few places near its southwest end almost cut through the peninsula. The Aleutian Range runs practically the entire length of the peninsula, and between Port Moller and the base of the peninsula it lies much closer to the Pacific side. This asymmetric position of the mountain range gives the south side of the peninsula a very bold, rugged appearance, but the north side is bordered by a wide lowland containing many lakes and swamps.

[9] Atwood, W. W., Geology and mineral resources of parts of Alaska Peninsula: U. S. Geol. Survey Bull. 467, pp. 13–15, 1911. Capps, S. R., The Cold Bay district: U. S. Geol. Survey Bull. 739, pp. 77–88, 1922.

GEOLOGIC RECONNAISSANCE MAP OF COLD BAY-CHIGNIK DISTRICT, ALASKA PENINSULA

The streams flowing southeastward into Shelikof Strait and the Pacific Ocean are mostly short, turbulent mountain streams with many falls, flowing through steep-sided canyons. This is especially true of those that reach the coast southwest of Wide Bay, where the mountains are rugged and close to the beach. Most of the creeks can be waded at favorable places; the larger ones, those flowing into Wide Bay, have eroded small valleys several miles upstream from their outlets and can be waded without danger except the one at the southwest end of the bay, which is a swift glacial stream. Aniakchak River is about 25 miles long and is the largest stream on the peninsula flowing toward the Pacific Ocean. It rises in Aniakchak Crater and empties into the northeast end of Aniakchak Bay. For the greater part of its course it flows through a valley about 6 miles wide, which has been partly filled with cinders thrown out from the crater. Near its mouth during the summer the river is about 100 feet wide and 4 feet deep. One of the tributaries, Hidden Creek, flows in a subterranean channel for 4 or 5 miles beneath the lava and cinders east of the crater.

The rivers and creeks flowing west and northwest across the lowland into Bristol Bay are sluggish, meandering streams, subject to tidal changes for many miles upstream. They rise along the northwest flank of the main Aleutian Range, where they are typical mountain streams for short distances before they enter broad valleys extending from the lowland through wide gaps in the lower mountain range toward the west. Both the valleys and the lowland contain many lakes, and the outlets of the larger lakes are usually rivers of moderate size. One of the larger bodies of fresh water in the area surveyed is Mother Goose Lake, which lies 10 miles west of Mount Chiginagak and receives the glacial streams flowing from the west side of the mountain. This lake has an area of about 16 square miles and contains eight small islands. The Ugashik Lakes, in the Cold Bay district northwest of Wide Bay, are two of the largest lakes on the peninsula, being surpassed in area only by Becharof and Naknek lakes. Upper Ugashik Lake is 17 miles long and has an area of approximately 85 square miles. Lower Ugashik Lake is irregularly circular in outline and has an area of about 100 square miles. The two lakes are connected by a short, narrow channel. On the banks of their common outlet, Ugashik River, several large salmon canneries have been in operation during the fishing season for a number of years. Becharof Lake is the largest lake on the Alaska Peninsula, as it is more than 40 miles long and has an area of about 450 square miles.

The Cold Bay district lies almost entirely within the limits of the mountainous area. The lower half of the Kejulik River valley and

the country north and west of Mount Peulik should be considered as merging into the lowland. In the immediate vicinity of Cold Bay the mountains rise abruptly from the shore line and attain a maximum elevation of about 2,500 feet. Between Cold Bay and the head of Kejulik River the mountainous belt narrows. Extending north and west from the coastal mountains is a broad valley containing a complicated network of meandering streams, large and small lakes and swamps, and here and there low hills standing out prominently in contrast to the low terrane about them. The trunk stream in this drainage network, Kejulik River, a tributary of Becharof Lake, lies nearest the northwestern wall of the valley and is a large sluggish stream whose water has a milky color due to its glacial origin. This stream in its lower reaches is deep enough for horses to swim. The Kejulik River valley is bounded on the northwest by a rugged sawtooth range, the Kejulik Mountains. This range extends northeastward from the northeastern shore of Becharof Lake and joins the coastal range in the vicinity of Mount Katmai. Mount Peulik, a volcanic peak nearly 5,000 feet high, lies across Becharof Lake about in line with the axis of the Kejulik Mountains. From Cold Bay to Portage Bay the coastal range is not so rugged, occupying a belt extending about 10 miles inland, with mountains 2,000 feet or more high. On the cape between Portage and Wide bays the mountains differ in character from those immediately to the northeast and are impassable by pack train, so that a three days' detour is necessary in traveling by land from one bay to the other. Southwest of Wide Bay there are many mountains some of whose peaks attain a height of 4,000 to 5,000 feet. The crest line between Wide and Amber bays is unbroken by any known low passes for 80 miles, so that the inland country behind these mountains is less accessible than the area west of the coast in the Cold Bay district. Along the upper slopes there are many permanent snow fields, and at several places vigorous alpine glaciers descend almost to sea level.

The most conspicuous topographic feature in the region southwest of Wide Bay is Mount Chiginagak, an active volcano at the head of Chiginagak Bay which rises 2,000 feet above its neighboring mountains and reaches an altitude of nearly 7,000 feet. It is regularly conical in shape; the summit is depressed, apparently by an extinct crater whose sides, as viewed from the north, appear in the form of two symmetrical cusplike peaks, which aid in giving the mountain an unusual scenic beauty. The upper 4,000 feet is almost entirely covered with snow fields and glaciers. A thousand feet from the top, on the north side, a white plume of vapors and sulphurous fumes rises from a small fumarole in the center of a snow field. This feature can rarely be seen from the coast, although it is nearer the

Pacific Ocean than most of the active and extinct volcanoes that occur at irregular intervals along the axial line of the Alaska Peninsula.

An extinct volcano that is less conspicuous but of considerably more scientific interest than Mount Chiginagak was discovered at the head of Aniakchak River, about 28 miles west of Aniakchak Bay. The crater is somewhat similar in size and shape to Crater Lake, Oreg., but differs in having a comparatively small body of water on its floor. The rim is almost circular in outline and has a diameter of 6 miles. The mountain summits that form the rim are from 700 to 1,500 feet above the crater floor and are unbroken except in the gorge or "gates" through which Aniakchak River flows. Within the large crater, near the east side, a cinder cone rises 1,000 feet above the general level of the floor and can be seen from the mountain tops northeast of the river. Three smaller cones also occur in the crater. The lake, on the northwest side, has an area of about 2 square miles; it is bluish green in color and does not appear to be deep. The area of the crater, including the cinder cones, is approximately 25 square miles. In places the walls are nearly vertical; where they are not so precipitous they are covered with small glaciers and snow fields. At the places where the walls were examined they were found to be composed chiefly of slightly folded sedimentary rocks. The bottom of the crater is filled with rather coarse black, gray, and red cinders which form ridges around the base of the large cone. The crater can be entered through the gorge on the southwest side of the river. The stream is too turbulent to be waded near the gorge but can be crossed within the crater just below the lake.

This remarkably large crater has been named Aniakchak, after the river whose source is within its walls. Unfortunately, little time was available for the investigation of this interesting crater. It was visited a short time August 26 and a few hours August 30. On the latter date W. R. Smith and Sidney Old went into the crater and attempted to reach the inner cone, but walking over the cinders is slow and difficult, and the summit of the cone was not reached, partly on account of darkness. The party's nearest camp was 6 miles from the "gates."

The mountains along the coast in the vicinity of Aniakchak and Kujulik bays are only 2,500 feet in altitude, but they are very rugged and sculptured by deep gulches.

West of and paralleling the main Aleutian Range a lower range of mountains extends from Lake Ugashik to Aniakchak Crater. This lower range is dissected by streams flowing west into Bering Sea from the slopes of the main range.

CLIMATE.

The Alaska Peninsula has an unusual climate, owing to its geographic position. The most notable features of the climate are the prevalent high winds and fogs, in explanation of which Capps[10] says:

> Any differences in barometric pressure that may exist between the north Pacific Ocean and Bering Sea result in winds that blow across the peninsula either from the northwest or from the southeast, and a complete reversal in the direction of the wind often takes place suddenly. Furthermore, any wind that blows is a sea wind, and the air, having a high moisture content, is chilled on passing over the mountain barrier and forms fog or clouds. Thus windy days are generally cloudy or foggy, and as windy weather is the rule, the mountain tops are generally in clouds. The few clear days that occurred in the summer of 1921 were relatively calm.

The Alaska Peninsula and the islands to the south are considered by Cleveland Abbe, jr.,[11] after studying the meteorologic records up to and including the year 1902, a distinct climatic province. It is characterized by less extremes of climate than many other parts of Alaska. The nearest meteorologic stations to the Cold Bay district and the country to the southwest are at Unga, on Unga Island; at Ugashik, at the mouth of Ugashik River; and at Kodiak, on Kodiak Island. The climatic records are not complete, but they serve to show that the precipitation is much less here than in southeastern Alaska or on the Aleutian Islands and that the extreme annual range of temperature is not so great as in the interior. Ugashik, on the west coast, has an annual rainfall of only 24.41 inches, and a range of temperature of 124°; Unga Island, off the east coast, receives about twice as much rain—48.78 inches—and has a temperature range of only 80° or 90°.

Rains are frequent in the summer, but the actual precipitation is not great, as the rains are usually in the form of a driving mist, with occasional heavy downpours. The summer is usually cool—so cool, in fact, that on rainy days a tent without some sort of a heating device is uncomfortable. There are exceptional days, however, as a temperature of 95° F. was recorded in June, 1922. The nights were uniformly cool, and the temperature dropped below freezing several nights during the later part of August. A few inches of snow fell during the night of August 2 in the vicinity of Mother Goose Lake, and early in September light snow fell upon the higher hills near Cold Bay. From June 14 to September 23, 1922, there were 30 clear days, most of which were calm, in the region between Portage and Chignik bays. The best weather oc-

[10] Capps, S. R., The Cold Bay district: U. S. Geol. Survey Bull. 739, p. 84, 1922.

[11] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, pp. 140, 150, 1906.

curred during the later part of June and the first two weeks of September.

The winters are severe, because of the cold, heavy winds, which are said to make traveling difficult and even dangerous for days at a time. The snowfall is said to be light, so that during a large part of the winter there is insufficient snow for sledding. This scarcity of snow makes it possible to winter horses without great expense, as the horses can forage for themselves during the day if some sort of night shelter is provided. The horses must be fed during short spells when the snow is deep. In some winters, such as that of 1920–21, the snowfall is so heavy that hay and grain must be fed throughout the bad weather. The snow usually disappears by July 1, except in deep gulches and on the higher mountain slopes. The ground does not freeze to a great depth.

VEGETATION.

The greater part of the Alaska Peninsula southwest of Naknek Lake is completely barren of trees. A rather surprising exception to the general lack of timber was found in several valleys east and southwest of Mother Goose Lake and in the immediate vicinity of Kejulik River. These valleys contain many clumps of cottonwood trees, some of which grow to a height of 35 feet and have a maximum measured diameter of 23 inches. The average height is probably 25 feet and the average diameter about 10 inches. Although the trees are partly protected from the Pacific Ocean winds by the Aleutian Range, which is unbroken in these areas, the tops of the larger trees are gnarled and bent, but the trunks are usually straight and of sufficient length to be useful in the construction of small cabins. The trees are too far from the Cold Bay oil field, however, to aid in solving the serious problem of building material there, and they would be of value only to prospectors or trappers in the valleys in which they grow. The high-bush cranberry grows in association with the cottonwood trees but was not seen elsewhere.

Alder and willow bushes are unevenly distributed in nearly all the valleys and at places on the mountain slopes 500 feet above sea level. In the valley at the southwest end of Wide Bay alder bushes reach a height of 18 feet but are usually stunted and gnarled so that it is difficult to penetrate the thickets. It is interesting to see the alders growing in small canyons with no branches extending above the level of the canyon walls, appearing almost as if they were constantly trimmed back to the level of the tops of the walls, thus showing the powerful effect of the heavy winds upon vegetable growth. At the lower elevations thickets of willow are common and

in sheltered places they attain a height of 10 or 12 feet, but in more exposed places they are stunted and twisted by the heavy winds, forming dense waist-high thickets.

The most abundant and conspicuous form of vegetation on the Alaska Peninsula is grass, which grows luxuriantly in all the valleys and lowland areas and also on the mountain slopes to a height of about 1,000 feet above the sea, in places where soil has accumulated sufficiently to permit a footing for vegetation. The grass, chiefly redtop, wild rye, and a smaller amount of bunch grass, grows rapidly and furnishes excellent grazing from the first of June until it is killed by frost in September. There are thousands of acres of this grass growing to a height of 3 or 4 feet, and it would make a fair grade of hay except for the difficulty of curing it properly, owing to the peculiar climatic conditions.

Several varieties of moss clothe the higher slopes and even the summits of the mountains that are not covered with snow or entirely barren of soil. These plants are widely distributed and are seen along the beach and in the lowland areas where the grasses and bushes do not crowd them out. Caribou moss (comprising various species of lichens) is seen occasionally throughout the district and is plentiful on several ridges south of Mother Goose Lake. Wild flowers in amazing variety grow everywhere from the valley floors to the highest altitudes at which vegetation is found. Nearly a hundred species were collected without any effort toward a careful and systematic search.

Several varieties of berries are found in the Cold Bay region, but only moss berries are abundant. In isolated patches blueberries are sufficiently plentiful to offer a welcome addition to the camper's stock of provisions. The dwarf cranberry grows very abundantly on the sand spit in Chignik Bay and forms an important article of food for the natives. Large yellow salmonberries are found at places along Aniakchak and Kujulik bays but are not very palatable.

Vegetation has gained a footing in patches in the valleys filled with cinders in the region around Aniakchak Crater, but there are large areas in these valleys that are entirely lacking in plant life.

The lack of timber immediately raises a question concerning fuel supply. The camper must depend upon the meager supply of alder brush for fuel, and camp sites must be chosen with that in mind rather than for other conveniences. Most of the permanent settlers in the country have erected buildings close to the beach, and the supply of driftwood has heretofore been ample for their needs both for building and for fuel. The buildings away from the coast are all of the type called "barabaras," which are sod houses built

around a framework of alder or any other available wood. The town of Kanatak is dependent upon coal shipped in by boat for its fuel supply. During the early stages of the boom the driftwood and the alder brush were sufficient for all needs, but the rapidly growing town demanded a greater supply of fuel. The petroleum residue patches furnish a small local supply of fuel that can be used under boilers. As mentioned elsewhere, the Associated Oil Co. plans to use residue from one of the patches on the Pearl Creek dome for fuel. During the drilling in 1903–4 the residue from the seepage at the head of Oil Creek, near Cold Bay, was used under the boilers and in stoves with satisfactory results. The supply of alder brush and driftwood is sufficient for the needs of the camper or for a small community, but a large community or any commercial enterprise must depend upon coal or oil.

ANIMAL LIFE.

Wild animals are not present in this part of the Alaska Peninsula in large numbers or great variety. The natives and a few white men trap for the fur-bearing animals each winter. The fox is the most abundant of the fur-bearing animals and is the most sought after. Many red fox and some silver-gray fox are taken each winter and are disposed of at the local trading posts by the trappers. Wolverine, mink, marten, and land otter are taken in small numbers. The brown bear is the largest animal on the peninsula and is occasionlly seen by travelers. The bears seem to be more numerous in the more remote parts of the peninsula. The large Arctic hare is probably very numerous, to judge from the number that were seen and the tracks and runs in the willow thickets. Moose, mountain goats, or sheep are not known in this area.

Caribou formerly ranged over the entire peninsula, but they have completely disappeared from many districts and are rarely seen on the peninsula above Mother Goose Lake. Southwest of Mother Goose Lake there is a small area in which about twenty caribou were seen. Farther southwest, near Aniakchak Crater, no caribou and very few tracks were seen. In the vicinity of Chignik Lagoon a few caribou are said to be seen occasionally. Those seen by the survey party were usually in pairs, but one herd of twelve came within a hundred feet of the pack train. They were rather small and belonged to the mountain type of caribou, which seldom migrate. Their presence in a small area is partly due to the fact that the caribou moss grows more abundantly in this particular area than elsewhere along the route of travel.

Hair seals are captured in the bays and form an important source of oil and food for the natives. The sealskins are used in the manu-

facture of moccasins, mucklucks, and other articles of clothing. The native's boat or bidarka consists of a framework of bent willows covered with tightly stretched sealskins.

Of the game birds ptarmigan were most plentiful in 1921 and 1922 but are reported to disappear almost entirely for periods of years. They are heavily preyed upon by eagles, foxes, wolverines, and bears. Ducks, geese, and swans breed in great numbers on the lakes, in the low marshy places, and in the lagoons along the coast. Other birds, including sea gulls, sea parrots, shags, and other sea fowl, are very plentiful and find favorable breeding places in the cliffs and on the islands. Small birds are not numerous; several species of snipes were seen on the beach; water wrens, magpies, and one or two other species were seen inland now and then.

A more favorable spawning ground for salmon can scarcely be found anywhere than the many lakes and streams in the lowland bordering Bristol Bay, and an extensive canning industry has been established along the larger rivers. The highly prized Alaska red salmon is the most prolific variety on the Bristol Bay coast. The Pacific streams have a smaller run of red salmon, but several other desirable varieties, including the king salmon, are abundant and supply the three large canneries at Chignik. These are the only canneries on the Pacific coast of the peninsula. In 1922 the Chignik canneries were limited by regulation to a pack of 50,000 cases each. Herring, halibut, and cod are said to be plentiful in the salt water along the coast. Only two kinds of fresh-water fish are known, the trout and grayling. These fish feed on the salmon eggs and the young salmon fry.

COMMERCIAL DEVELOPMENT.

There have been two periods during which outside interests have attempted to develop the Cold Bay district into a commercially producing oil field. The first attempt was in 1903–4, when five or six wells were drilled to depths ranging from 15 to 1,500 feet. Two companies operated in the field at that time, making their headquarters at Cold Bay. Just inside the cape at the southwest entrance to Cold Bay, in a small protected valley, one of the operating companies erected several substantial frame buildings that are still standing and in good condition. A road 7 or 8 miles long was built from the buildings at Cold Bay north along the shore to Trail Creek and up that stream to its headwaters on the upland, where the wells were drilled. Drilling operations were begun in the summer of 1903 and were continued until October, 1904. No commercial quantity of oil was obtained from any of the wells, although a thick residual oil was reported from several strata penetrated by one of the deeper wells.

From October, 1904, until the fall of 1910 no important oil developments occurred. In 1910 all the oil lands were withdrawn from entry, no title having been granted to any claims in this region. The next ten years was marked by a lack of interest in the prospects for oil. In 1920 Congress passed an oil-leasing bill that permitted the staking and drilling of oil lands, and a great revival of interest was manifested immediately, as several prospectors hastened to the Cold Bay district, and before the snow had disappeared most of the promising oil land had been staked. This restaking of oil claims marked the beginning of the second period of commercial development of the district.

Prospecting and surveying was carried on vigorously during 1920–1922, and examinations were made by geologists representing the United States Geological Survey and several oil companies. In August, 1922, two steamers landed drilling equipment at Portage Bay, and soon the town of Kanatak, at the head of Portage Bay, was the center of great activity. During two or three weeks Kanatak changed from a town with a population of 10 or 15 to a typical boom town with a population of nearly 200 and tents, log cabins, and frame buildings numbering 100 or more. Work was immediately begun on a road connecting Kanatak and the site selected for drilling, which is 17½ miles northwest of Kanatak. The Standard Oil Co. of California and the Associated Oil Co. are now operating in the field. The Standard Oil Co. has a standard rig and the necessary equipment to drill to a depth of 4,000 feet. Power is to be furnished by a 75-horsepower gasoline engine. The Associated Oil Co. has two portable Star rigs and intends to use local petroleum residue as fuel.

POPULATION.

The population of this district is normally small but is greatly influenced by commercial activity. During the period of active development work from 1902–1904 a number of people were engaged in road work and drilling. The base camp at Cold Bay was constructed of substantial frame buildings, which were used as a trading post until the fall of 1921. The trading post for many years was the center of activity for the district, being the post office and source of supplies for the trappers and the natives. The winter mail for Bristol Bay and Nome was formerly carried across the peninsula from Cold Bay by dog team. From 1904 until 1920 the permanent white population was limited to one or two at the trading post and a few trappers and prospectors. In 1920 many prospectors went into the region to stake claims and the United States General Land Office established some of the land lines, so

that the claims could be definitely described. Most of the early prospectors who staked claims did not stay on the ground, but as interest in the area increased and several oil companies examined the promising structural features many of the prospectors returned to protect their interests. Although the only store in the region was at Cold Bay no activity was manifest there, as it was too far from the prospective oil field. The native village of Kanatak, at the head of Portage Bay, became the center of activity. In 1921 two frame buildings were erected there for stores, and several smaller frame cabins were built. The post office and store were moved from Cold Bay to Kanatak. Building and preparations for building continued on a small scale commensurate with the gradual influx of people until August, 1922, when the drilling equipment for the oil companies arrived. The population increased from 10 or 15 white people to about 200 within two or three weeks, and tents and frame buildings of all descriptions were hastily erected to furnish accommodations for these people. A townsite was laid out, and an attempt was made to regulate the location of buildings so that a future readjustment would not be necessary. In the fall of 1922 people were still arriving at Kanatak on every boat, so that it is impossible to give even an approximately accurate figure for the population. The future population of the town must depend upon the success attained in the drilling, as there is no other activity in the district that could sustain so many people.

Southwest of Kanatak the Alaska Peninsula is very sparsely inhabited in the area covered by this report. Between Wide and Chignik bays there are no permanent inhabitants either along the coast or inland, except at the canneries near the mouth of Ugashik River. At least one white man has lived at Wide Bay for the last 20 years. During the winter several trappers operate inland from the heads of some of the bays along the Pacific coast. These men find employment in the canneries at Chignik during the canning season. Since 1920 there have been several oil prospectors and land-survey parties staking claims or running lines west and southwest of Wide Bay and also west of Aniakchak Bay. Few of these men remain in the country during the winter, as the weather does not permit much out-of-door work. A few people engaged in fox farming occupy some of the smaller islands south of Aniakchak and Chignik bays.

At Chignik three large salmon canneries operate about eight weeks of the summer and employ more than 300 white men during the canning season. These men are brought to the canneries either from Seattle or from San Francisco in the companies' ships, which return

to the States at the end of the season with the men and a cargo of canned salmon. The population at Chignik is reduced in the winter to 8 or 10 white people and 25 natives.

There is a small native settlement at Kanatak which has a population that varies during the year. In the winter there are 40 or more natives huddled in their small sod houses (barabaras), but in the summer they scatter, some going to the Bristol Bay side of the peninsula to work in the canneries and others to the small native village at the head of Becharof Lake, where they catch and dry salmon for winter food. Only one family of natives normally resides at Kanatak during the summer. There is a small settlement of natives at Chignik and other small villages still farther southwest. These natives belong to the Aleut tribe, which inhabits the western part of the Alaska Peninsula. It is doubtful if there are any pure-blooded Aleuts at Kanatak and Chignik, as many of them plainly show Russian admixture, and it is probable that all of them have at least a small amount of Russian blood. The natives are all members of the Russian Orthodox Church. Each village has a church, usually a substantial frame building, which presents a great contrast to the barabaras or partly underground huts in which the people live. The natives still speak the Aleutian language, although many of them understand Russian. They are not a thrifty set of people, and their only source of income is hunting, trapping, and fishing, with occasional odd jobs for the white men. Their main article of food is the dried salmon, which they put up in the summer, when fish are very plentiful.

ROUTES AND TRAILS.

The Alaska Peninsula is difficult of access by land but relatively easy by boat. Travel on the peninsula in the summer time is confined to the mountains, as the western lowland is practically impassable to man, except by boat on the large sluggish streams. There are few good harbors, as most of the bays are either open to the sea, offering no protection to boats in storms, or have dangerous unmapped rocks and reefs that make them unsafe for large boats. The bays giving possible access to the prospective oil fields are Wide, Portage, and Cold bays. These bays were uncharted in 1922, but they were examined by representatives of the oil companies, and Portage Bay was chosen as the most favorable. Subsequent charting of Portage Bay and Wide Bay by the United States Coast and Geodetic Survey has shown that Wide Bay is the better harbor, as it is wide and deep and offers a well-protected anchorage for large boats. Portage Bay offers no protection from south or southeast winds, and the bay is shallow, so that large boats can not approach close to the shore. About three-quarters of a mile from

the head of the bay is a reef, seen at low tide, that extends from the northeast shore nearly two-thirds of the distance across the bay. This reef gives some protection to small boats, but there is not enough anchor room for large boats between the gently sloping beach and the reef. There are no wharf or docking facilities at Portage Bay or at any other bay along this part of the coast of the Alaska Peninsula except at the three canneries. At Chignik all freight must be handled off Kanatak by small boats or lighters, which are privately owned. If the Pearl Creek dome proves to be commercially productive, better harbor facilities must be provided.

Most of the freight and passengers for the Cold Bay district are routed through Seward or Kodiak. During the summer there are four passenger boats a month from Seattle to Seward and two a month to Kodiak. During the winter the scheduled number of sailings is less. The trip to Seward requires seven or eight days and to Kodiak eight to twelve days, depending upon the route followed. From Seward a mailboat having accommodations for a few passengers and a small amount of freight sails once a month for Alaska Peninsula ports. From Kodiak small boats can be hired to transfer passengers or freight to Portage Bay, the trip requiring about 24 hours. In the spring of both 1921 and 1922 the Seattle steamer made one trip into Portage Bay, and doubtless the steamer would make Portage Bay a regular port of call if the amount of business warranted it and if some quick and reliable means of unloading were furnished. Two large freight steamers were chartered by the oil companies to deliver the drilling equipment at Portage Bay, and both steamers lay at anchor in the bay for several days and unloaded their freight by lighters, being fortunate in having calm weather. Any large steamer anchored in Portage Bay would be compelled to steam out into open water in the event of a storm, as it could not ride out a severe storm in the shallow water of the unprotected, rock-bound bay.

Travel within the district is fairly easy by foot or with a pack train, as many trails have been beaten out by the numerous parties that have moved around in the district during the last two years. There are numerous easy passes across the mountains into the interior lowland. Kanatak has been the headquarters of all the parties working in the district, and the trails radiate from that point. The wagon road under construction from Kanatak to the well sites will make the country around Mount Peulik easily accessible from Kanatak. A good trail for pack horses can be followed from Kanatak to Cold Bay, the last 7 or 8 miles being over the wagon road that was built in 1903 but is no longer suitable for the use of wagons. From the head of Cold Bay there is an easy pass into the Kejulik Valley, but at high tide a bold headland on the west shore of Cold Bay ex-

tends into the water and at low tide large boulders make it very dangerous to take pack animals around the point. Just south of the headland is a large creek known as Teresa Creek or Schooner Creek, and near the head of its valley an easy trail may be followed into the Kejulik Valley. The Kejulik Valley may also be entered through one or two low passes from small bays northeast of Cold Bay, but most of these bays are too shallow even for small boats at low tide. Within the Kejulik Valley itself travel is not so easy unless the foothills are followed closely, and even then swampy ground will give some difficulty. A short distance away from the foothills swamps are the rule, and travel with a pack train is extremely difficult. Kejulik River is a glacial stream that is somewhat difficult to cross, as it is cold, swift, and deep. In its lower reaches it is too deep for a horse to wade, but in its upper part many places can be found where a man can wade it. Over a large part of the valley moss grows luxuriantly, making travel both slow and tiresome.

The country northwest of the mountains between Wide and Aniakchak bays had not been traveled by pack train before the summer of 1922. The best route of entrance to the district from the east, so far as known, is either by the Aniakchak River valley or by the valley at the southwest end of Wide Bay. The country could easily be reached by means of small boats going up the rivers from Bristol Bay. The route followed by the Geological Survey party lies between the main range along the coast and the lower range to the northwest. Only slight difficulties for traveling by pack train were encountered, although several detours in the valleys were necessary to avoid swampy areas. The ridges or spurs extending from the main range toward the west are rarely more than 1,000 feet above the valleys at the most favorable points of crossing. Steep slopes could not always be avoided, and as they were often obscured by fog traveling was slow and uncertain. Occasionally short stretches of trail had to be cut through the alders and cottonwoods. A trail leads up the valley of Lee Creek at Wide Bay and across the divide to the Ugashik Lake anticline. This is one of the best routes to the oil field. At Aniakchak the best route for travel by pack train is along the beach, as the area between the beach and the hills to the west is swampy; but at Kujulik Bay the best route is on the benches back of the beach. Near the southwest end of Kujulik Bay a trail leads across the mountains toward the west. At low tide the beach at Chignik Bay, except at a few places, can be traversed. A wagon road has been graded from the coal mines on Thompson Creek, Chignik Bay, to the little bunker on the beach, but it is seldom used. A footpath follows the benches above the beach from the bunker to the sand pit.

Aniakchak and Kujulik bays are uncharted and are avoided by seagoing boats, although Aniakchak Bay is reported to be deep in places and is protected by Sutwik Island from southwest winds.

GEOLOGY.

GENERAL FEATURES.

The field work on which this report is based was undertaken primarily to locate, if possible, areas in which the geologic structure is favorable for the accumulation of oil, and only the principal geologic features are here considered. The recent investigation was a combined reconnaissance topographic and geologic survey, and although every advantage possible under the conditions of rapid traveling was given to the writers, it was not expedient to retard the topographic work greatly in good weather to afford time for making a close investigation of interesting geologic features. In a reconnaissance examination of this sort little time is available for the careful tracing of the contacts between formations.

The sedimentary rocks occurring on the Alaska Peninsula (see Pl. VIII) were deposited during the Mesozoic and Cenozoic eras and range, with many interruptions in their sequence, from the Upper Triassic to the Recent. A complete section of the sedimentary series does not occur at a single locality, and correlation must be made from one part of the peninsula to another by means of the fossil remains of animals and plants. Only a brief description of the formations will be given here, as they have been described in detail in other publications[12] and correlated with exposures in other parts of the Alaska Peninsula and with the beds at the type localities.

[12] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, pp. 50–59, 1905; Notes on the petroleum fields of Alaska: U. S. Geol. Survey Bull. 259, pp. 134–139, 1905. Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, pp. 393–397, 401–402, 1905. Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, 1911. Capps, S. R., The Cold Bay district; U. S. Geol. Survey Bull. 739, pp. 77–116, 1922. Spurr, J. E., A reconnaissance in southwestern Alaska: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 31–264, 1900.

Generalized section of the sedimentary rocks in the Cold Bay-Chignik district.

System.	Series.	Formation.	Lithologic character.	Thickness. (feet).
Quaternary.	Recent.		Terminal moraines, glacial erratics, mountain outwash, stream gravel, silt, and beach deposits.	
	Pleistocene.			
Tertiary.	Eocene.		Fine conglomerate, sandstone, shale, and thin beds of lignite.	2,000±
Cretaceous.	Upper Cretaceous.	Chignik formation.	Sandstone, conglomerate, shale, and coal seams.	400-780
		Unconformity		
Jurassic.	Upper Jurassic.	Naknek formation.	Conglomerate and arkosic sandstone from 500 to 3,000 feet thick at base, overlain by sandstone, sandy shale, and conglomerate.	5,000±
		Shelikof formation.	Upper 700 to 1,000 feet, black shale with some limestone lenses at top; rests on a thick series of sandstone, with minor amounts of conglomerate and sandy to calcareous shale, carrying Chinitna fauna.	5,000-7,000
		Unconformity		
	Middle (?) Jurassic.	Kialagvik formation.	Sandstone and sandy shale at Wide Bay.	500+
	Lower (?) Jurassic.		Calcareous sandstone, sandy shale, and limestone at Cold and Alinchak bays.	2,300±
Triassic.	Upper Triassic.		Thin-bedded limestone and calcareous shale intruded by basaltic dikes and sills at Cape Kekurnoi.	1,000+

In the southwestern part of the area recently investigated the sedimentary rocks are mainly of Tertiary and Upper Jurassic age. The formations bordering Chignik Bay consist of Upper Jurassic, Upper Cretaceous, and Tertiary sedimentary rocks, overlain and intruded by igneous rocks. In the inland country between the Cold Bay and Chignik districts large areas consist of volcanic rocks and most of the sedimentary beds are of Tertiary age.

The Upper Triassic beds exposed on Cape Kekurnoi are the oldest sedimentary rocks known on the peninsula. The thickness of the exposed beds is estimated to be over 1,000 feet. They are composed of sharply folded, partly metamorphosed limestone and calcareous shale intruded by basaltic dikes and sills. The limestone is thin bedded and is black to bluish gray when freshly broken but becomes light gray upon weathering. The shale is of various colors from red to light brown.

Conformably above the rocks of known Triassic age a series of about 2,300 feet of beds is exposed along the north shore of Cold Bay. These rocks have furnished fossils that are presumably of Lower Jurassic age though not well enough preserved for positive identification. The beds consist chiefly of sandstone, limy shale, and impure limestone. The rocks are somewhat contorted and faulted; their area is small, and they have not been recognized on the Alaska Peninsula except back of Cape Kekurnoi.

Middle (?) Jurassic rocks are represented by a narrow belt of the Kialagvik formation on both sides of the southwest end of Wide Bay. These beds are partly covered by glacial drift, but where they are exposed in contact with the overlying Upper Jurassic rocks there is evidence of an angular unconformity. Fossils have been found in the Kialagvik formation at many localities. A few species from this formation are identical with or closely related to the Tuxedni fauna of Tuxedni Bay, and T. W. Stanton considers the Kialagvik formation of either earliest Tuxedni age or slightly older. The beds consist of about 500 feet of sandstone, sandy shale, and fine conglomerate. The base of the formation is not exposed.

The oil seepages in the Cold Bay district occur in the Upper Jurassic series of rocks, which has been divided into the Shelikof and Naknek formations. The Naknek formation, which is the younger, is exposed throughout the eastern Becharof Lake and Ugashik Lake drainage basins and extends southwestward to the vicinity of Mount Chiginagak, where it is intruded by large masses of igneous rocks and overlain unconformably by the Tertiary rocks. Small areas of the Naknek formation are exposed south of Wide Bay and east of Aniakchak Crater. The Shelikof formation is very thick and forms the coastal mountains between Cold and Portage bays and is present in the mountains west and southwest of Wide Bay.

Along the west shore of Chignik Bay and continuing northwest at least as far as Hook Bay Creek, Upper Cretaceous rocks of the Chignik formation are exposed. The Chignik formation is about 900 feet thick at Chignik Bay. Its extent northwest of Hook Bay Creek is unknown. The beds rest unconformably upon the Naknek formation and are overlain in places by volcanic rocks. The strata are mainly sandstone, shalc, and conglomerate, with some valuable coal seams.

Southwest of Mount Chiginagak an area of Tertiary rocks extends to the north side of the upper Aniakchak River valley. The area is about 40 miles long and from 8 to 16 miles wide. Where the rocks were examined, on the north and south sides of the area, they are in contact with large masses of intrusive rocks. The deposits are entirely continental so far as observed, and only plant remains were found in them. They are about 2,000 feet thick and

rest unconformably upon a massive gray sandstone, which, although no fossils were seen in it, is presumed to be the upper part of the Naknek formation. The Tertiary beds consist of shale, sandstone, and conglomerate and thin seams of lignite.

The surface rocks in the valleys of streams flowing from the Aleutian Range consist of glacial drift, much of it in the form of small moraines. Most of the drift was deposited by recent glaciers and is composed of unstratified sand, clay, and boulders. Along the north side of Wide Bay a narrow strip extending about 1 mile inland is covered with older drift, which is probably of Pleistocene age. The valley floors of nearly all the streams within a radius of 20 miles from Aniakchak Crater are filled with pumice and black volcanic cinders. In Lava Creek the cinders attain a thickness of over 300 feet and form high, steep terraces above the stream. The hills north and west of the crater are covered to an unknown depth with cinders.

The igneous rocks on the Alaska Peninsula are chiefly of volcanic origin and nearly all of Tertiary age. In the north-central part of the peninsula the older intrusive rocks crop out in a rather broad belt extending southwestward almost continuously from Naknek Lake to the country west of Chignik Bay. Near Mount Chiginagak and also along the southwest side of the Aniakchak River valley the central intrusion is connected with another belt of igneous rocks forming the core of the Aleutian Range southwest of Wide Bay. The greater part of the cape between Portage and Wide bays is made up of an igneous mass extending inland as far as Lake Ruth. The mountains bordering Kujulik and Hook bays are almost entirely composed of rocks of volcanic origin. Dikes and sills are intruded in nearly all the sedimentary formations. The igneous rocks differ in composition and texture from one area to another.

The rocks of the southeast side of the Alaska Peninsula are folded into several more or less well defined roughly parallel anticlines and synclines whose axes extend southwest, in general conformity with the direction of the peninsula. Most of the folds are broad structural features, with dips generally not exceeding 16°. The anticlines are rather persistent but are interrupted at places by igneous intrusions or by major faults.

SEDIMENTARY ROCKS.

TRIASSIC ROCKS.

The Upper Triassic rocks that crop out on Cape Kekurnoi, at the northeast entrance to Cold Bay (see Pl. VIII), are the oldest sedimentary rocks exposed on the Alaska Peninsula. Beds of Triassic age are not known elsewhere on the peninsula, but it is possible that they underlie large areas and might be encountered by deep drilling

at Wide Bay. A detailed section of the Upper Triassic rocks has not been made, but in general the lower beds, which are contorted and crumpled, consist of hard, dense thin-bedded limestone and limy shale cut by dikes and sills of basalt. The upper beds become less calcareous and more sandy until finally a dense sandstone is encountered, in the upper part of which are found Jurassic fossils. The transition from limestone to sandstone is very gradual, and there is no evidence of an unconformity; the Triassic formation is therefore considered to end where the sandy phase begins. The upper beds of the series are not so greatly crumpled and dip 10°–20° NW.; the strike is northeast, conforming in general to the strike of the thick overlying Jurassic beds. Calcite stringers are abundant in the limestone.

The limestone beds in the lower part of the formation contain large numbers of the widely distributed Upper Triassic fossil shell *Pseudomonotis subcircularis* Gabb, and a few specimens of a fossil hydrozoan, *Stoliczkaria*, were collected, belonging to a species known only from this locality in North America but found in the Triassic of Europe.

The contact of the Upper Triassic and Lower (?) Jurassic formations has not been followed across the cape, but the areal extent of the former is probably very small, not exceeding 3 or 4 square miles. It is exposed along the beach at Alinchak Bay, the next indentation northeast of Cold Bay, where the succession as reported by Martin[13] consists of basic igneous rock at the bottom, succeeded by contorted cherts that have yielded no fossils, and these in turn overlain by shale and limestone yielding *Pseudomonotis*.

JURASSIC ROCKS.

Most of the sedimentary beds of this region were deposited during Jurassic time. The only known sedimentary beds on the peninsula that are older than Jurassic are the Triassic rocks just described.

The rocks included in this group represent largely shoreward phases of sedimentation. Limestone, which indicates deposition in deep water or clear shallow water, is entirely absent above the Triassic except where it occurs as large concretions in the upper part of the Shelikof formation and as smaller concretions in shaly beds in the Naknek formation. Sandstone is the most abundant and is predominantly arkosic. The coarseness of grain of much of the sandstone is a good indicator of shallow-water deposition, but the evidence supplied by the nature of the bedding is more conclusive. Much of the sandstone is cross-bedded, and in many places it is interbedded with conglomerate. The conglomerate is abundant. Some

[13] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, p. 58, 1921.

beds are only a few inches thick; others occur as a series 1,000 feet or more in thickness with a minor amount of arkosic material. The material of which they are composed ranges in coarseness from fine grits to boulders several feet in diameter. These beds of conglomerate, included in formations composed of marine sediments, can represent nothing else than deposition in shallow water under shore conditions, as these large boulders must have been deposited close to their source. Shale is abundant, but less so than the coarser sediments, and even the shale is inclined to be sandy rather than argillaceous. Still other indications of the shoreward phase of sedimentation are the fossil plants that are found in the sandstone and the small lenses and seams of lignitized wood, which indicate the presence of vegetation during the process of sedimentation and therefore shallow-water, near-shore conditions.

LOWER (?) JURASSIC ROCKS.

Sedimentary rocks of Lower (?) Jurassic age crop out on Cape Kekurnoi, where they conformably overlie the Triassic limestones described above. (See Pl. VIII.) These rocks occupy a few square miles in a narrow strip crossing the cape that separates Cold Bay from Alinchak Bay, to the northeast. This strip is the only known area of Lower (?) Jurassic rocks on the Alaska Peninsula. The beds show a gradual transition from the underlying Triassic limestone into the impure limestone and calcareous sandstone and shale that form the basal part of the Lower (?) Jurassic. There appears to be strict conformity between the two formations, and the paucity of fossils makes it difficult to determine the contact. The poorly preserved fossils collected include several ammonites which in form and sculpture suggest Lower Jurassic genera, such as *Arietites*, *Aegoceras*, and *Amaltheus*, but it has not been possible to make positive identifications. The sedimentary beds tentatively included in the Lower Jurassic are 2,300 feet thick. The 1,500 feet at the bottom may be divided into two parts—a lower part consisting mainly of limestone and limy sandstone and shale and an upper part in which there is a narrow zone characterized by conglomerate and sandstone containing abundant bright-red jasper pebbles, brightly colored greenstone particles, and fragments of carbonaceous shale. The 800 feet at the top of the formation is composed of a black to rusty sandy shale with some thin beds of limestone. No fossils were found in this shale, but on the basis of lithology and field relations it is tentatively included in the Lower Jurassic.

MIDDLE (?) JURASSIC ROCKS.

KIALAGVIK FORMATION.

The Kialagvik formation, of Middle (?) Jurassic age, occurs along the sides of the southwest end of Wide Bay and continues a

short distance inland along the base of the mountains beyond the head of the bay. (See Pls. VIII and XI.) This formation is of especial interest, because it consists of the oldest rocks exposed along the crest of the Wide Bay anticline and is the only probable representative of Middle Jurassic time on the peninsula. It was named the Kialagvik formation from the native name for Wide Bay, along whose shore has been found the only outcrop of the formation on the Alaska Peninsula. On the northwest side of the bay the formation occurs as a narrow strip about a mile wide extending from a point near the mouth of Lee Creek to a point nearly 3 miles up the broad glacial valley at the southwest end of the bay. The beds exposed in the bluffs along the shore back of the sand spit and farther southwest at the base of the mountains belong to this formation. The rocks on the northwest side of the bay consist of sandstone, sandy shale, and conglomerate, which on Short Creek are intruded by several small dikes and sills. The greater part of the area is covered by glacial drift and by a dense growth of alders and grasses, so that the contact with the overlying Upper Jurassic formation is difficult to follow. In the valleys and on the shore southeast of Lee Creek where the contact was observed there is evidence of an angular unconformity between the two formations. The unconformity is most pronounced at the bluff near the mouth of Lee Creek, where the shale beds of the Kialagvik strike S. 45° E. and the overlying conglomerate and the beds in the hills west of the bay strike southwest. Here the Kialagvik beds can best be examined at low tide. Toward the head of the bay they are nearly horizontal or have very slight dips to the northwest.

The extent of the Kialagvik formation along the southeast shore of the bay was not determined, but it does not crop out at the point of land projecting toward the islands. On this side of the valley the rocks are hidden by vegetation. At the base of the first small glacier, 2½ miles up the valley, only Upper Jurassic rocks were recognized. The beds of the Kialagvik formation dip 6° S. on the southeast side of the bay and consist of perhaps 200 feet of coarse sandstone and a few thin beds of fine conglomerate. From a short distance the rocks appear to be colored light red, but a freshly broken surface of the sandstone is bluish. The greater part of the valley at the head of the bay is probably underlain by the Kialagvik formation.

The formation is abundantly fossiliferous. Some of the fossils have led T. W. Stanton to correlate this formation with the lower part of the type section of the Tuxedni sandstone at Tuxedni Bay, on the west shore of Cook Inlet, or with beds slightly older—a correlation which would indicate that these rocks represent only the lower part of the Middle Jurassic. During at least the greater part

of Middle Jurassic time either this portion of the Alaska Peninsula stood above sea level, or else sediments were laid down that were subsequently removed by erosion. It is probable that there was a long period of erosion during the later part of the Middle Jurassic epoch and that the sediments laid down early in the period were partly removed at Wide Bay and entirely removed at Cold Bay.

The fossils that were collected from the Kialagvik formation at Wide Bay have been determined by T. W. Stanton as follows:

11349. No. F 13. South shore at southwest end of Wide Bay:
Rhynchonella sp.
Pinna sp.
Pecten sp.
Inoceramus lucifer Eichwald?
Trigonia sp.
Dactylioceras? sp.
Belemnites sp.
These fossils probably belong to the Kialagvik fauna.

11350. No. F 14. West shore of Wide Bay south of Short Creek. Stratigraphically 150 feet above collection F 31:
Ostrea sp.
Trigonia sp., Glabrae group.
Protocardia sp.
Tancredia? sp.
Pleuromya dalli (White).
Natica sp.
Hammatoceras howelli (White).
Hammatoceras? kialagvikensis (White).
Harpoceras whiteavesi (White).
Kialagvik fauna.

11351. No. F 31. Capps locality 104, Wide Bay:
Pecten sp., smooth form.
Gervillia sp.
Trigonia sp., Glabrae group.
Pleuromya dalli (White).
Natica sp.
Hammatoceras howelli (White).
Harpoceras whiteavesi (White).
Kialagvik fauna.

11352. No. F 15. Wide Bay, 1 mile up creek southwest of Short Creek:
Pecten sp., smooth form.
Lima sp. related to L. gigantea Sowerby.
Inoceramus lucifer Eichwald?
Dactylioceras? sp.
These fossils apparently belong to the Kialagvik fauna.

11353. No. F 16. Wide Bay, 1 mile up Short Creek:
Inoceramus lucifer Eichwald?
Belemnites sp.
Probably Kialagvik fauna.

11357. No. F 30. 1 mile northwest of Lee's cabin at Wide Bay:
Inoceramus lucifer Eichwald?
Inoceramus sp. Larger form with coarse concentric ribs.
Jurassic, probably Kialagvik.

11358. No. F 32. Float found on point at Wide Bay:
Inoceramus lucifer Eichwald?
Stephanoceras? sp.
The fragment of a small ammonite (Stephanoceras?) in this lot is closely related to if not identical with a form in the Tuxedni sandstone and thus apparently gives another tie between the Tuxedni and the Kialagvik.

The species of the Tuxedni fauna described by White have been referred by Pompeckj to the upper Lias—that is, the upper part of the Lower Jurassic. Hyatt said that the nearest relatives of the fauna are in the "lowest parts of the Inferior Oolite, in formations placed by many German and French authors in the upper Lias." On account of the relationship which the fauna shows to the Tuxedni fauna Stanton refers it to the lower part of the Middle Jurassic.

UPPER JURASSIC ROCKS.

SHELIKOF FORMATION.

The lower part of the rocks of Upper Jurassic age in the Cold Bay region is called the Shelikof formation, from the fact that it is the chief outcropping formation on the northwest shore of Shelikof Strait from Katmai Bay to Wide Bay. (See Pl. VIII.) The upper contact of this formation can be traced throughout the district and is marked by a heavy shale member overlain by the coarse basal conglomerate of the Naknek formation. The lower contact was observed by Capps at only two places—at Wide Bay, where the Shelikof formation unconformably overlies sandstones of Middle (?) Jurassic age, and on the northeast shore of Cold Bay, where the Middle (?) Jurassic is entirely absent and the Shelikof rests on Lower (?) Jurassic rocks. Although the lithology of the formation as a whole is not constant, the uppermost member, a massive black shale 700 to 1,000 feet thick, containing numerous limestone lenses and concretions, is observed in every section. This shale member is poorly fossiliferous, but its position, underlying the heavy basal conglomerate of the Naknek formation, leaves no doubt concerning its horizon. Below the massive shale member is 4,000 to 4,700 feet of massive brown to gray sandstone with minor amounts of shale and conglomerate. The shale beds are thicker west of Wide Bay than between Cold and Portage bays, but the sandstone is not so thick, and the total thickness at the extreme southwest end of Wide Bay is less than at Cold Bay. The lower 1,500 feet of the formation along Lee Creek is chiefly shale with some limy and concretionary phases. At the base of the shale a bed of coarse conglomerate lies unconformably upon the Kialagvik formation. A dark massive sandstone, resembling an oil-impregnated sandstone that occurs on upper Trail Creek

at Cold Bay, is exposed in the mountains 2 miles west of Wide Bay. The sandstone is about 50 feet thick in the mountains between the main and west branches of Lee Creek.

The sandstone and shale are locally calcareous, and the sandstone is in places little more than a sandy shale. The sandstone is also concretionary in many places, the concretions ranging from small well-rounded bodies a few inches in diameter to large irregular, poorly defined masses. At Wide Bay the lower 1,500 feet of the formation is mostly shale with some limy lenses and concretions. At Cold Bay the lower part of the formation is sandstone with a conglomerate at the base, and below the conglomerate is 800 feet of shale that is tentatively included in the Lower (?) Jurassic as described above. This thick series of shale beds, however, contains no fossils by which its age could be determined, and possibly the shale does not belong in the Lower Jurassic but is the age equivalent of the lower shale at Wide Bay.

The beds on the islands in Wide Bay differ lithologically from other sections of the Shelikof formation and are not fossiliferous. A detailed section of the strata along the southwest shore of the large island opposite Lee Creek is as follows:

Section on island in Wide Bay.

	Feet.
Thin-bedded bluish shale with lenses of limy concretions	50
Coarse arkosic sandstone with seamlets of coal about 1 inch thick and thin beds of shale	100
Massive gray sandstone and thin beds of shale	105
Thin-bedded sandstone alternating with beds of shale	325
Very massive hard brown to light-gray sandstone	585

The islands consist of rocks of the Shelikof formation except several small ones near the northeast entrance of the bay, which consist entirely of igneous rocks. The beds on the islands and the point of land projecting toward the islands on the southwest side of the bay dip 6°–24° SE. and form the southeast flank of the Wide Bay anticline. The prevailing dips on the mainland are to the northwest. Several faults, including one of perhaps 800 feet displacement, occur in the vicinity of Lee Creek. Some of the shale beds contain lenses of limestone nodules which weather to a conspicuous light-yellow color. A freshly broken nodule consisted of dark-blue, nearly pure limestone yielding the characteristic Upper Jurassic ammonite *Cadoceras*.

Cadoceras is found throughout that part of the formation below the uppermost shale member, and as this same fossil is characteristic of the Chinitna shale at its type locality at Chinitna Bay, on Cook Inlet, this part of the Shelikof formation can be definitely corre-

lated with the Chinitna. The type section of the Chinitna formation is not as thick as the Shelikof formation, and there is considerable difference in lithology. The Chinitna attains a maximum thickness of 2,400 feet on Chinitna Bay; the Shelikof is 6,000 to 7,000 feet thick at Wide Bay. The type section on Chinitna Bay is composed predominantly of shale. The uppermost member of the Chinitna formation is a series of dark massive shales 500 to 1,000 feet thick, containing numerous concretions and lenses of impure limestone and a few fossils. The uppermost members of the Chinitna and the Shelikof are comparable, but there the analogy ceases, as the rest of the Shelikof is largely sandstone and the rest of the Chinitna is practically all shale; moreover, as mentioned above, there is a great disparity in thickness. The Shelikof formation and the Chinitna shale are approximately contemporaneous, but the conditions of sedimentation in the two regions were obviously somewhat different.

The Shelikof formation has an economic significance in the Cold Bay district, as it is in this formation that the hopes for a petroleum industry are centered. Considerable black shale is intermixed with the sandstone of the formation, and it is believed that this shale may possibly be the original source of the petroleum. Under proper structural conditions the heavy shale member at the top of the Shelikof would form a good cap rock to prevent the escape of imprisoned gas and oil. Most of the seepages in the Cold Bay district come from the Shelikof formation and are approximately alined along the Bear Creek-Salmon Creek anticline and its prolongation. The seepages near Pearl Creek issue from the overlying Naknek formation, but it is possible that the petroleum has been released from the Shelikof formation by fissures or minor faults.

NAKNEK FORMATION.

The Naknek formation is probably the most extensive surface formation of sedimentary rocks on the Alaska Peninsula. (See Pl. VIII.) The term was originally applied by Spurr [14] to a series of arkose and intercalated sills of lava in the vicinity of Naknek Lake, but the name has since been used to include a great series of sediments, distributed over a wide area on the Alaska Peninsula and the west side of Cook Inlet. The Naknek formation attains a great thickness and is well exposed in the drainage basins of Becharof and Ugashik lakes and also west of Wide Bay in the vicinity of Deer Mountain. It probably extends continuously from Naknek Lake to the north side of Mount Chiginagak, where it is intruded by large masses of igneous rocks that form a group of mountains northeast and west of the volcano. For 40 miles southwest of these moun-

[14] Spurr, J. E., A reconnaissance of southwestern Alaska: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 169–171, 1900.

tains only Tertiary rocks were recognized. The Naknek formation is again exposed near the divide of Aniakchak River and Lava Creek. The occurrence of Upper Jurassic rocks between the area visited near Mother Goose Lake and the Pacific coast was indicated by the presence of float rock containing Naknek fossils at the head of one of the westward-flowing streams.

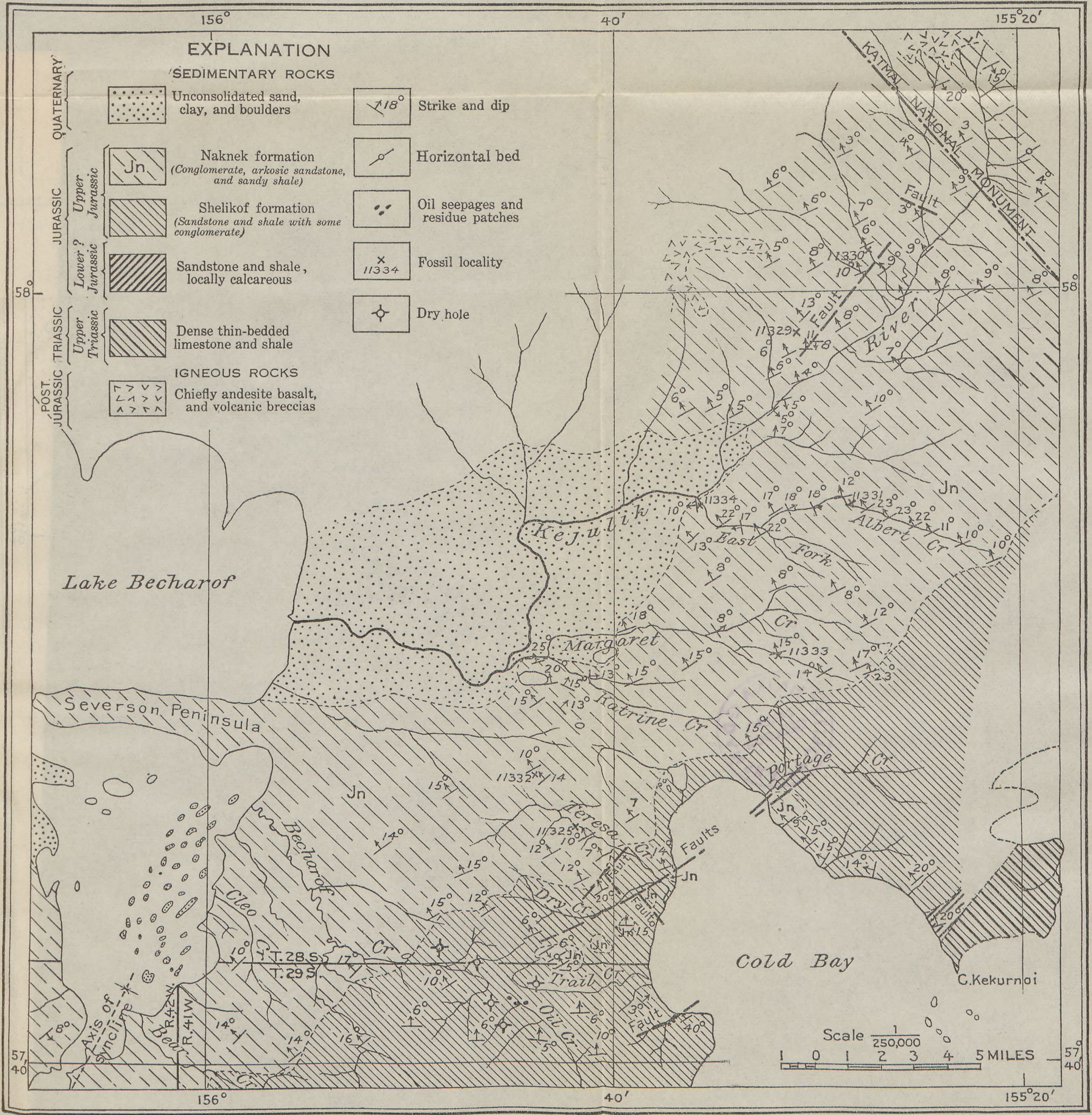
The base of the Naknek formation, wherever observed in this region, is characterized by a coarse conglomerate conformably overlying the upper shale member of the Shelikof formation and making the two formations easily separable on the basis of lithology. The conglomerate is in places separated from the shale by a varying amount of coarse arkosic sandstone. The conglomerate is composed of well-rounded boulders of granitic material in an arkosic matrix. The boulders range in size from small pebbles to large rounded masses of rock 6 or 8 feet in diameter, or even larger. As would be expected in so coarse a sedimentary deposit, there is great lateral variation in character of material and in the thickness of the formation. The conglomerate is interbedded with arkosic sandstone, and laterally it grades into the sandstone either by thinning out or by a gradual change in the coarseness of the material. Northeast of Cold Bay the conglomerate itself is much finer than that between Cold Bay and Portage Bay, as few boulders over a foot in diameter were seen, and the average diameter was not more than 2 or 3 inches. Near the crest of the range southeast of the upper part of the Kejulik Valley the conglomerate at the base of the Naknek formation was estimated to be 40 feet thick and is overlain by 500 feet of coarse arkosic sandstone, which in turn is overlain by several hundred feet of finer-grained sandstone. In the vicinity of Pearl Creek there is a massive conglomerate nearly 900 feet thick underlain by several hundred feet of interbedded sandstone and conglomerate and overlain by arkosic sandstone and massive conglomerate, the whole series being approximately 2,500 feet thick. In tracing the conglomeratic phase of the basal Naknek southwestward from Cold Bay it can be observed to thicken gradually from 500 feet near the head of the Kejulik Valley to the enormous thickness exposed in the vicinity of Pearl Creek and Deer Mountain. There appears to be no break in sedimentation within the formation, so it is probable that more detailed work will show that the thick series of conglomerate and arkose in the Pearl Creek area changes into finer sediments toward the northeast, and that the relatively finer sandstone and shale overlying the conglomerate in the Kejulik Valley were deposited at the same time as the upper part of the coarser sediments.

A conglomerate lying at the base of the Naknek formation has been mapped as a separate formation on the west shore of Cook

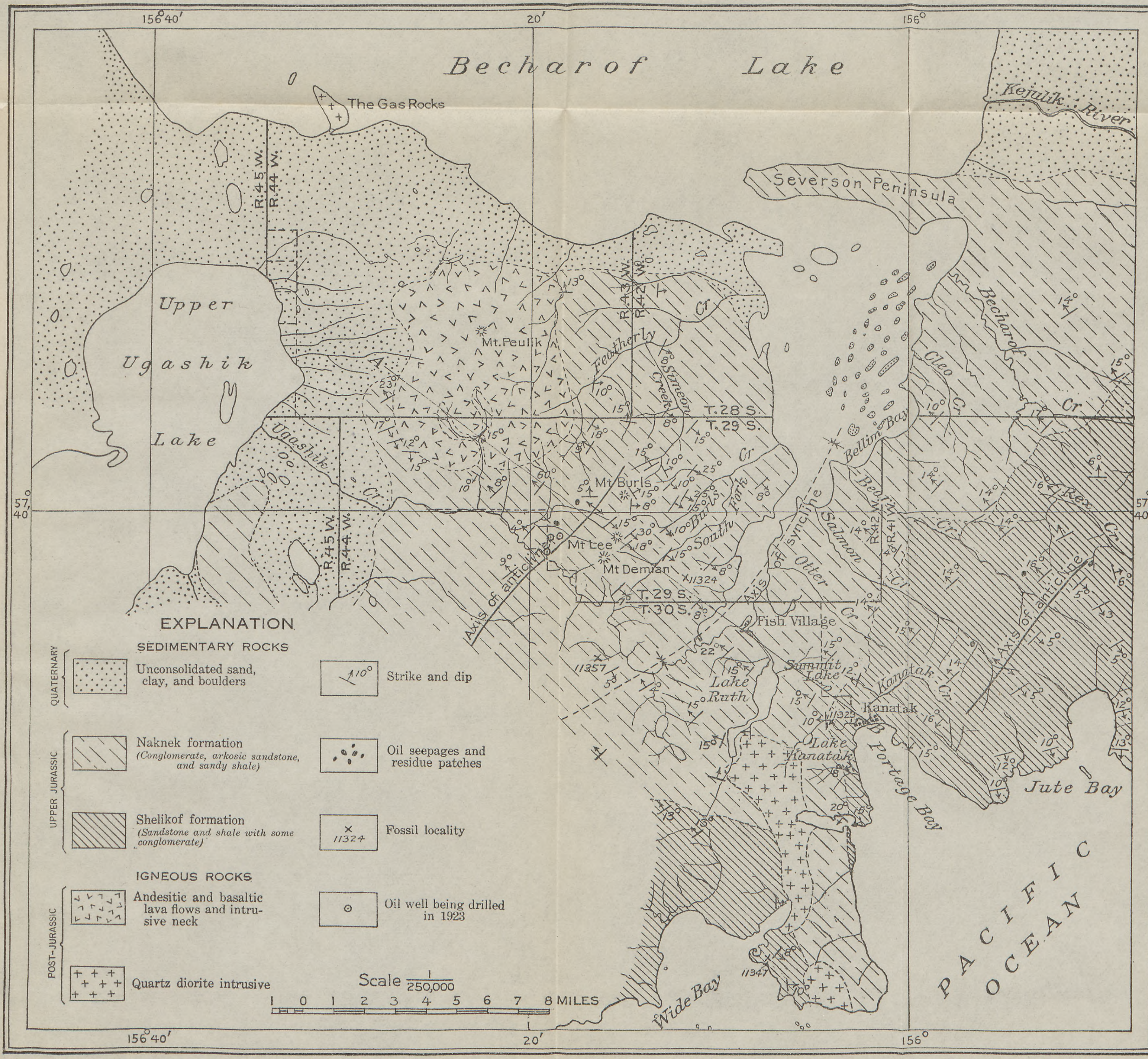
Inlet.[15] This conglomerate is typically exposed on Chisik Island in Tuxedni Bay and has been named the Chisik conglomerate. It occurs below the Naknek formation as there mapped and overlies the Chinitna shale, which is the equivalent of at least a part of the Shelikof formation, and therefore this conglomerate is in the same relative position as the conglomerate exposed in the Cold Bay district. The Chisik conglomerate closely resembles the conglomerate at the base of the Naknek formation at Cold Bay, as it is composed of large well-rounded boulders of granitic material. No fossils could be found in the conglomerate of either area, but the stratigraphic position and lithologic character of the conglomerate at Cold Bay suggest its correlation with the Chisik conglomerate. It would be difficult to map the conglomerate at Cold Bay as a separate unit, however, because of its great lateral variation in thickness and in coarseness. Furthermore, it appears to be an integral part of the Naknek formation, and in the writers' opinion it should be classed as the basal part of the Naknek and so mapped, rather than distinguished by a separate name.

Between Mount Peulik and the south arm of Becharof Lake a thick section of the Naknek formation is exposed. (See fig. 2.) Here the basal 2,500 feet of conglomeratic and arkosic beds are overlain by 1,600 feet of sandstone that is mainly arkosic but does not contain any interbedded conglomerate. Above this sandstone is about 1,500 feet of sandy shale that Capps considered as representing the highest Naknek beds outcropping in the region and is well exposed on the west shore of the southern arm of Becharof Lake. These beds make a total thickness of about 5,600 feet of the Naknek. The rocks exposed around the old crater of Mount Peulik consist largely of sandstone and conglomerate that are similar in character to the conglomeratic phase of the lower part of the Naknek formation, but they contain more sandstone, are about 1,600 feet thick, and are overlain by about 700 feet of sandy shale which immediately underlies the lava flow on the southeast side of the crater. The stratigraphic position of the beds beneath the lava flow is somewhat in doubt, but it is probable that they are to be correlated with the shale beds exposed along the upper arm of Becharof Lake. West of the old crater is exposed a series of sandstone and conglomerate which may be higher in the stratigraphic section than the shale member underlying the lava flow. There is no great thickness of consolidated sedimentary rocks west of the crater between the edge of the lava flow and the unconsolidated Recent deposits near the shore of Ugashik Lake, under which the sedimentary rocks dip.

[15] Martin, G. C., and Katz, F. J., Geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 68, 69, 1912. Moffit, F. H., The Iniskin Bay district: U. S. Geol. Survey Bull. 739, p. 119, 1922.



GEOLOGIC SKETCH MAP OF KEJULIK VALLEY.



GEOLOGIC SKETCH MAP OF VICINITY OF PEARL CREEK DOME AND MOUNT PEULIK.

A—B, Line of section in Figure 2.

No fossils could be found in these rocks, but lithologically they can not be distinguished from the underlying rocks of known Naknek age, so they are provisionally included in that formation. Extensive faults were not observed around Mount Peulik, but it is probable that considerable movement has taken place, making the determination of the correct stratigraphic position of the strata a problem requiring detailed work.

The rocks of the Naknek formation that crop out in the Kejulik Valley (see Pl. IX) are somewhat different in lithology from those just described, which crop out around Mount Peulik and on the Pearl Creek dome. They are of much finer grain considered as a whole and contain a greater amount of shale. The beds appear to be enormously thick, but the apparent great thickness is thought to be due in part to repetition of the same beds by faults, although only a few minor faults were seen in the valley. An estimate of the thickness made from the dips of the beds across the valley without postulating faults gives a thickness of 11,000 feet.

The basal conglomeratic phase, as described above, thins from a series 2,500 feet thick at Pearl Creek to about 500 feet of coarse arkosic sandstone with 40 feet of conglomerate near the base in the Kejulik Valley section. Overlying this coarser phase and continuing across the Kejulik Valley, as far as the survey was carried, the rocks consist mainly of fine arkosic sandstone with numerous thick beds of dark shale. This variation in the character of the sediments from Pearl Creek to the Kejulik Valley is natural in view of the differences in proximity to the source and the rate of sedimentation that must have prevailed. These rocks were mainly deposited in shallow water, as most of the sandstones are cross-bedded and some of them contain lignitized plant remains. To supply sediments so coarse as those that make up the Naknek formation in the Cold Bay field erosion must have been very rapid, and the material must have been transported by short, swift streams, as this coarse material could not have been moved far from its source. Such conditions, though commonly observed to persist during short periods, rarely continue for so long a period as that represented by the basal part of the Naknek formation.

The fossils that were collected from the Naknek formation in 1922 have been determined by T. W. Stanton as follows:

11323. South side of creek that drains Kanatak Lake:
   Pteria sp.
   Nucula sp.
   Cardium?
   Jurassic. Formation not determinable from these fossils; possibly Naknek.

11324. In gulch 2,250 feet S. 60° E. from forks in south fork of Burls Creek:
Aucella sp. related to A. erringtoni (Gabb).
Inoceramus sp.
Astarte sp.
Phylloceras sp.
Belemnites sp.
Jurassic; Naknek.

11325. Three miles up Teresa Creek from shore:
Pecten sp.
Pteria sp.
Aucella sp. related to A. bronni Lahusen.
Nucula sp.
Pleuromya sp.
Jurassic; Naknek.

11332. One mile north of saddle at head of Teresa Creek:
Aucella sp.
Nucula sp.
Astarte? sp.
Patella sp.
Undetermined small slender gastropod.

11333. Basal Naknek on west side of range across from Alinchak Bay:
Aucella sp. related to A. bronni Lahusen.
Nucula sp.
Pleuromya sp.

11334. 1600 feet southwest of junction of East Fork and Kejulik River:
Aucella pallasi Lahusen?
Lima sp.
Pteria sp.
Jurassic; Naknek.

11329. About 1 mile northwest of Kejulik River and 2 miles southwest of point where two large tributaries come into river:
Pecten sp.
Lima sp.
Astarte sp.
Jurassic; Naknek.

11330. Two miles up from Kejulik River along eastern of two tributaries mentioned under 11329:
Pecten sp.
Lima sp.
Lima? sp.
Aucella sp.
Leda? sp.
Astarte sp.
Turbo? sp.
Jurassic; Naknek.

11331. In canyon near head of East Fork of Kejulik River:
Anomia? sp.
Lima sp.
Aucella sp, related to A. erringtoni (Gabb).
Pleuromya sp.
Belemnites sp., large phragmacone.
Jurassic; Naknek.

11363. No. F 37. Shale on bank of Kejulik River, northeast of Becharof Lake:

Amberleya sp. This is a fine specimen, but the range of the species is not known.

11344. No. F 1. Kanatak. From shale just beneath Naknek, 100 feet higher stratigraphically than Capps locality 1–79 (1921).

Pteria sp.
Nucula sp.
Grammatodon sp.
Astarte sp.
Belemnites sp.
Jurassic; nothing distinctive to decide between Chinitna and Naknek.

11345. No. F 7. Across divide at head of Ugashik Creek.

Cidaris? sp., fragmentary imprint.
Pholadomya sp.
Phylloceras sp.
Jurassic; probably Naknek.

11346. No. F 8. Shale just below Naknek conglomerate. West bank at head of north branch of Big Creek, Wide Bay:

Cidaris? sp.
Ostrea sp.
Pteria sp.
Grammatodon sp.
Solemya sp.
Turbo? sp.
Undetermined gastropod.
Apparently belongs to same fauna as 11344, probably Naknek.

11359. No. F 33. Gates of crater, head of Aniakchak River:

Aucella pallasi Keyserling?
Pleuromya sp.
Phylloceras? sp.
Naknek fauna.

11360. No. F 34. Fossil Creek, north of Lake Becharof. Collected by Dr. Laymore:

Aucella pallasi Keyserling?
Naknek fauna.

11348. No. 12. Erma Bay, south of Wide Bay:

Lima sp.
Aucella pallasi Lahusen.
Naknek.

11354. No. F 18. 8 miles southwest of Wide Bay:

Aucella sp. related to A. erringtoni (Gabb).
Fragments of undetermined ammonite and belemnite.
Naknek fauna.

11356. No. F. 26. East bank, near head of Lava Creek:

Aucella sp. related to A. bronni Lahusen.

The highest part of the Naknek formation north of Mount Chiginagak consists of a thick series of dark-yellow to brown sandy shale which lies above the interbedded conglomerate and arkosic sandstone. The shale is somewhat similar in appearance to the shale in Ugashik Mountain and yields the same fossils—several species of *Aucella*.

The uppermost member of the Naknek formation exposed near the headwaters of Aniakchak River and Lava Creek consists of about 200 feet of very massive light-colored sandstone, which is not fossiliferous and does not show any bedding planes. Throughout its thickness it is reticulated with a network of calcite veinlets, which in places are so numerous that the rock appears almost white and can be recognized from a distance. Many small slickenslides occur in the sandstone. It is possibly the uppermost member of the Naknek formation known on the peninsula. The sandstone is overlain unconformably by the Tertiary formation. The rocks lying conformably beneath the sandstone consist of brownish thin-bedded sandy shale that is similar in character to the sandy shale near Mount Chiginagak and Becharof Lake and yields the same species of fossils. The base of this shale is not exposed in the Aniakchak district. The base of the mountains forming the east side of Aniakchak Crater is composed of sedimentary rocks belonging to the Naknek formation. The unconformity between Upper Jurassic and Tertiary rocks can be plainly seen on part of the inner wall of the crater. The extent of the formation southwestward from the crater is not known, but it occurs in the mountains at the head of Hook Bay Creek and inland west of Chignik Bay.

UPPER CRETACEOUS ROCKS.

CHIGNIK FORMATION.

Sedimentary rocks of Upper Cretaceous age are represented only in the extreme southwestern part of the area examined during the summer of 1922. These rocks, occurring along the west shore of Chignik Bay, on Chignik Lagoon, and on the upper part of Hook Bay Creek (see Pl. VIII), were studied and mapped in 1908 and later described by Atwood.[16] The Chignik formation consists of sandstone, shale, conglomerate, and some valuable coal seams. These beds rest unconformably upon the Naknek formation and are overlain by vast quantities of volcanic tuff and basic lava flows in the Hook Bay area north of Chignik Bay proper. The sandstone members of the formation range from fine even-grained sediments to grits, and some of the sandstone has a light-green color when fresh but weathers to black and shades of brown. The conglomerates are conspicuous members in the series, but they are not as thick as those of the lower Naknek, although similar in appearance, consisting of pebbles of granite, greenstone, and quartz as large as 4 inches in diameter. There are lenses of shale and sandstone in some of the

[16] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, pp. 41–48, 109–114, 1911.

conglomerate layers. Concretions and ripple marks are seen at many places in the sandstone beds.

The extent of the Chignik formation northeast of the head of Hook Bay Creek was not determined, but it probably does not extend more than a few miles, for the rocks in that area as seen from a mountain top west of Kujulik Bay appear to be volcanic. The beds on Hook Bay Creek strike N. 15° E. and dip 8°–60° SE. There is evidence of much faulting, although only minor displacements were noted. The beds at this locality consist chiefly of sandstone, with minor amounts of shale, conglomerate, and coal.

The Upper Cretaceous sedimentary rocks yield both plant and shell fossils. Several collections of shells were made at the head of Hook Bay Creek and northwest of the sand spit on Chignik Bay. The Chignik fauna is in part somewhat similar to that of certain beds in the Chico formation of California and in the Nanaimo on Vancouver Island.

TERTIARY ROCKS.

Tertiary rocks occupy an area of at least 600 square miles between Mount Chiginagak and the north side of the Aniakchak River valley. (See Pl. VIII.) This area, which is about 40 miles long and from 8 to 16 miles wide, forms a narrow basin between the main Aleutian Range on the southeast and the lower range on the northwest. These mountains bordering the Tertiary formation consist of intrusive igneous rocks. The Tertiary rocks are possibly of late Eocene or Miocene age. No invertebrate fossils were obtained from them, but several lots of fossil plants, which Arthur Hollick has identified, were collected from the upper part of the formation.

The beds in the area between Mount Chiginagak and Aniakchak River have a total thickness of at least 2,000 feet and are composed of shale, conglomerate, and sandstone, with some thin seams of lignite. East of Mother Goose Lake the lower 800 feet of the formation consists predominantly of bright-colored shale and thin beds of sandstone. These thick beds of shale were seen only at one locality. The base of these beds is not exposed, and their relation to the overlying sandstone and conglomerate was not determined. The upper 200 feet of the shale does not yield fossils; the lower beds exposed were not closely examined. The carbonaceous shale and thin lignite beds of the formation at other localities were entirely lacking in these shale beds. A section of the overlying beds is as follows:

Section of upper Tertiary beds between Mount Chiginagak and Aniakchak River.

	Feet.
Uppermost beds of bituminous shale yielding fossil plants; thin beds of sandstone and conglomerate	300±
Coarse dark to light gray sandstone and fine conglomerate	105
Light-yellowish shale with thin seams of lignite near the top	75
Coarse thin-bedded sandstone containing pebbles near the base	80
Yellow shale with 6-inch seams of lignite	65
Alternating beds of sandstone and shale	80
Chiefly shale with thin beds of pebbly sandstone	580
Coarse massive sandstone	50
Dark thin-bedded shale	40
	1,370

The beds are not persistent and the stratigraphic sequence could not be recognized from one locality to another, except the beds containing fossil plants, which occur over a large part of the area. Northeast of Aniakchak River the greater part of the section below the fossiliferous shale consists of thick beds of fine to very coarse conglomerate. The pebbles are as much as 3 inches in diameter and are usually worn very smooth. They consist of rocks of volcanic origin; occasionally a bright pebble of jasper is seen, and locally quartz pebbles are numerous. The pebbles are cemented by a matrix of hard coarse greenish sandstone which forms about half of the rock material. The following section was measured near the contact of a large intrusion:

Section of upper Tertiary beds 10 miles southwest of Mother Goose Lake.

	Feet.
Coarse pebbly sandstone and conglomerate	30
Light-colored sandstone, fine conglomerate, and minor amounts of shale	65
Coarse massive sandstone and fine conglomerate	40
Sandy shale and thin beds of limy shale	55
Pebbly arkosic sandstone and conglomerate	75
Sandy blue and yellow shale	40
Arkosic pebbly sandstone and conglomerate; some thin beds of fine-grained sandstone	70
Unexposed	75
Sandy limestone	20
	470

This section represents the highest Tertiary beds that were examined and is higher than the preceding section.

The strike of the beds in the entire area is predominantly southwest and the dip from a few degrees to 40° NW. There are local changes in strike, and in a few places the dips are reversed, but in

general the whole area has been tilted upward and forms a monocline on the west flank of the Aleutian Range. The formation is not greatly faulted, although a fault of considerable displacement was noted southwest of Mount Chiginagak. Many small intrusions of andesite and granodiorite in the form of dikes, sills, and a small laccolith occur in the formation. A few miles northwest of the lower Aniakchak River valley the Tertiary rocks are overlain by vast quantities of volcanic tuff and breccia. In the lowland at the head of Aniakchak Bay there are several exposures of pebbly sandstone beneath the volcanic rocks. The age of these rocks was not determined, but they are probably Tertiary. Thin beds of coal are reported from the cape between Aniakchak and Kujulik bays and indicate either Tertiary or Cretaceous rocks.

The rocks west of Amber Bay are of sedimentary origin, but they were not examined, and their age is unknown. The upper beds are probably Tertiary. The strike of these rocks is N. 60° E. and the dip 18°–22° W.

QUATERNARY DEPOSITS.

The Alaska Peninsula has been the scene of active glaciation, but the glacial deposits that now remain there are not very abundant. There are two types of valleys, which may be classed as glacial and postglacial. The postglacial valleys are relatively small and V-shaped, but all the larger mountain valleys are of the typical U-shape due to scouring out by glacial erosion. Many of the present streams head in small glacial cirques, and some of the cirques contain small lakes of clear water. The only glacial moraines observed in the Cold Bay district were between Mount Peulik and Becharof Lake. The topography of that part of the district is the typical morainal topography, with low mounds like so many piles of débris and numerous small lakes hidden away among the hills. The moraines wherever visited are composed entirely of volcanic material of the same character as the lavas that were poured out from Mount Peulik. It is believed that these moraines represent the deposits from a slowly retreating small alpine glacier that descended from the volcanic peak.

The Kejulik Valley contains no terminal moraines in the area visited. The valley itself, during glacial time, contained a trunk glacier fed by numerous small glaciers that entered from nearly all the tributary valleys on the northwest side and from some of those on the southeast side. Some erratic boulders of basaltic rock are seen on the low hills and elsewhere in the main valley, regardless of the topography. Most of the tributaries of Kejulik River, entering from the northwest side, flow through wide, deep, U-shaped valleys showing the scouring effect of the ice that previously almost

filled them. At present there are small tongues of ice at the heads of most of these valleys, and the water of Kejulik River has the milky color characteristic of streams of glacial origin.

Glacial drift, some of which is probably of Pleistocene age, occurs at a few localities in the region southwest of the Cold Bay district. Small patches of glacial material occupy the intervalley areas in the slightly elevated irregular plain between the west shore of Wide Bay and the mountains. These deposits are not conspicuous and are probably not thick, although in many places they obscure the underlying consolidated rocks. The greater part of the drift is unassorted and has the heterogeneity of material and size characteristic of glacial till. It is composed of clay, sand, gravel, and large boulders. Many of the boulders are striated and are smooth and flattened on one side. In the higher mountains there is evidence of vigorous glacial activity during Pleistocene time. The broad, steep-sided valleys extending inland from the heads of the bays are undoubtedly the result of ice scouring. Cirques, U-shaped valleys, and rounded surfaces of bare rock are common physiographic features that indicate extensive glaciation in the region. The greater part of the morainal material was either carried directly to the sea or has been washed away by recent streams. Many of the valleys and the lowland in the northwestern part of the peninsula probably contain more or less glacial material of Pleistocene age which has been worked over and redeposited in recent time.

In the high mountains of the Aleutian Range between Wide and Aniakchak bays numerous small glaciers, some of which are several miles long, exist at the present time. Morainal deposits at the heads of the valleys, especially southwest of Wide Bay and around the base of Mount Chiginagak, are formed by these glaciers. Most of the streams that carry the finer material from the glaciers build deltas of mud and clay in the lakes or bays.

Recent deposits of alluvium, glacial drift, beach sand, delta sand, and pumice form the surface material of many of the valley bottoms and stretches of sea and lake shores. The alluvium consists of unconsolidated clay and gravel which have resulted from the erosional work of streams, waves, and wind. Sand dunes and old sea beaches occur at the heads of many of the bays. Between Aniakchak Bay and the hills to the west nine crescent-shaped beaches can be distinctly seen in the form of low ridges, conforming in direction to the present shore line. The nature of the geologic work did not permit accurate mapping of the alluvium, but the larger areas have been indicated on the map. (See Pl. VIII.)

On the northwest slopes of Mount Peulik the streams have cut deep, narrow valleys into a thick series of unconsolidated gravel, composed of subangular basaltic pebbles and boulders which range

from a fraction of an inch to several feet in diameter. In some places the streams have cut 30 or 40 feet into the gravel. This gravel is believed to be outwash from the mountain, the streams being greatly augmented by the great banks of snow that accumulate on the mountain side each year. Still higher on the mountain boulders of basaltic rock 10 or 12 feet in diameter are scattered promiscuously on the surface; these were transported to their present position by melting snow and the action of gravity.

Large quantities of pumice and fine volcanic ash have been thrown out of Aniakchak Crater over the surrounding country in Recent time. Much of the ash has been washed from the mountains and concentrated in the valleys. (See Pl. VIII.) The thickness of these deposits ranges from an inch of fine material 25 miles from the crater to at least 200 feet at the head of Lava Creek, 5 miles from the base of the crater. The physiographic features of the area within a radius of 10 miles indicate the enormous amount of material that was ejected from the crater. The bottoms of the Aniakchak and Meshik river valleys have been completely filled with ash and cinders. At the present time the valley floors form a broad, nearly level plain with a few isolated sharp-peaked mountains surrounded by the ash deposit. Since the eruption the streams have been continually transporting pumice and the fine ash to the sea. Small pieces of pumice can be seen moving rapidly along the bottom of Aniakchak River. Some of the transported material forms bars in the bay, but much of it has been thrown back on the beach and has made a remarkable series of sea beaches.

IGNEOUS ROCKS.

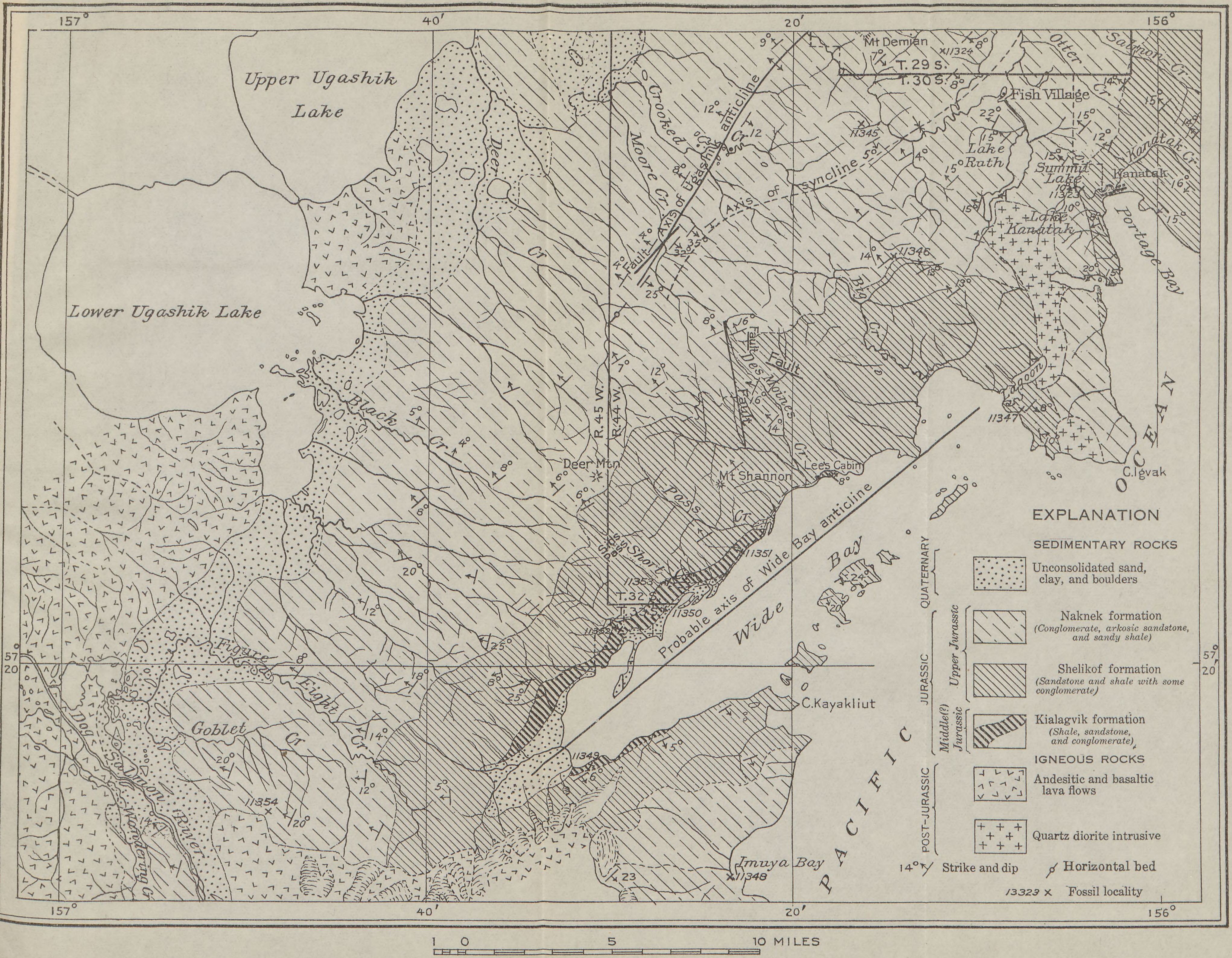
A variety of igneous rocks are seen in the Cold Bay region, but most of them are the result of volcanic activity. A quartz diorite stock forms the rugged hills on the promontory between Portage Bay and Wide Bay. (See Pls. VIII, X, and XI.) A few dikes that are not shown on the maps cut the Triassic limestones and the beds of the Shelikof formation. Mount Peulik, the most striking topographic feature in the region, is a recently extinct volcano standing on the rim of an older crater. Lavas from these craters have spread over a moderate area in all directions. North of Mount Peulik, on the south shore of the main body of Becharof Lake, is a volcanic neck surrounded by a greatly dissected cinder cone. North of Cold Bay are the Kejulik Mountains, with their lava-capped ridges and jagged peaks of igneous rocks.

Cape Igvak, between Portage Bay and Wide Bay, with its high, rugged mountains, is composed of plutonic igneous rock. The intrusive body is about 10 miles long and 2 miles wide, elongated in a nearly north-south direction. On the seaward sides, except at the

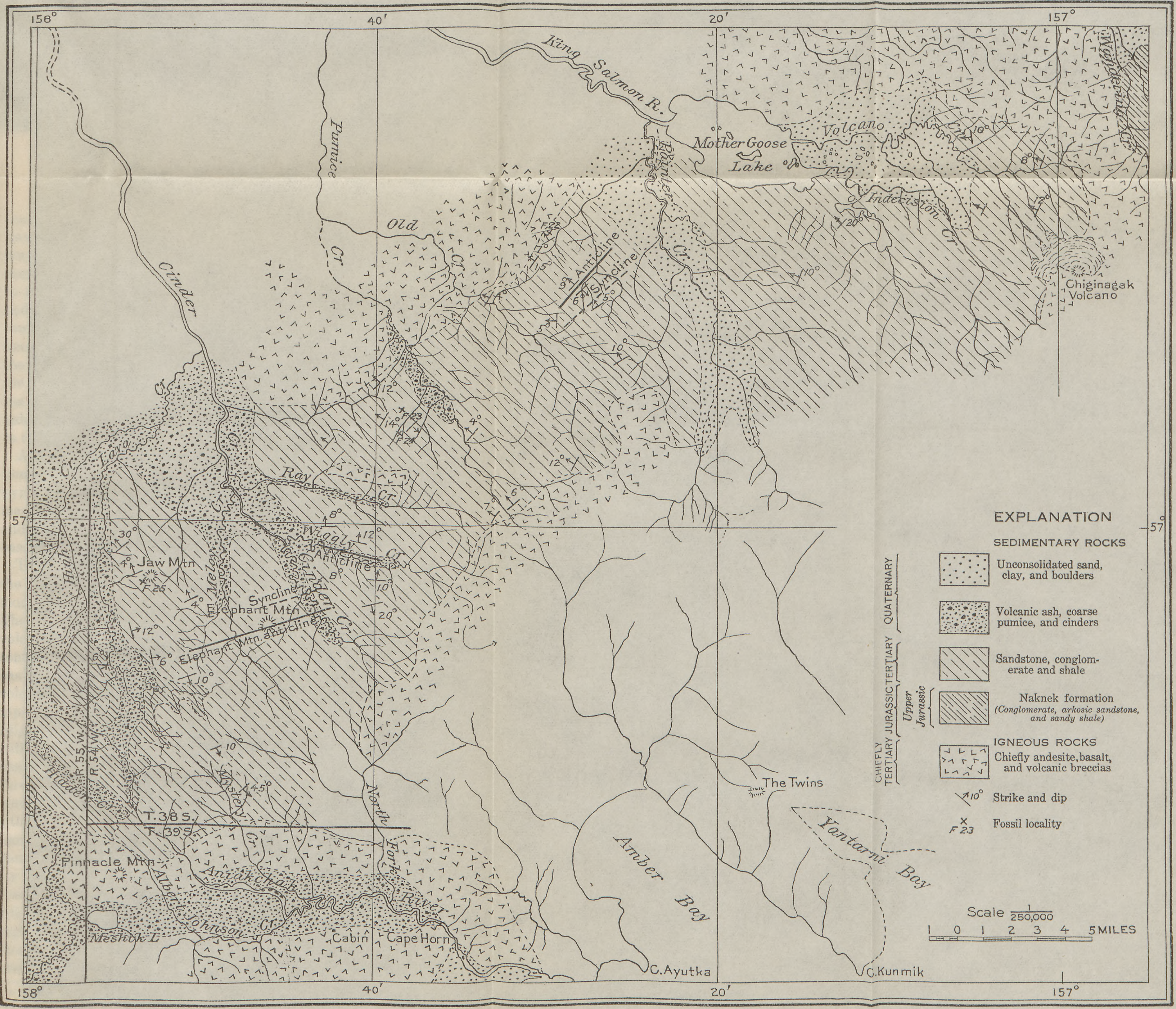
outer extremity of Cape Igvak, the intrusion is bordered by a narrow fringe of sedimentary rocks, which have been altered by the heat and hydrothermal action attending the intrusion. The sedimentary beds are cut by the intrusion but not flexed. Good exposures of the contact between the intrusive rock and the sediments can be seen at several places, but easily accessible points are in the cirque above Kanatak Lake, near the head of the lagoon on the west side of Portage Bay, and at the head of the lagoon indenting the cape at the northeast end of Wide Bay. The most striking feature that impresses the observer from a distance is the rich brown color of the hills adjacent to the intrusion, which is in marked contrast to the more somber color of the hills elsewhere in the region. Upon closer examination the sediments are found to be richly impregnated with pyrite, which, when exposed to the agents of weathering, becomes oxidized and imparts the familiar iron-oxide coloring. Abundant tourmaline is found near the contact as a black fibrous aggregate in thin sheets or in masses several inches in diameter in the igneous rock. Small veins composed almost wholly of magnetite cut the igneous rock at Kanatak Lake. The igneous rock is a quartz diorite and is a medium to coarse grained light-colored rock in which abundant black glistening flakes of biotite and crystals of hornblende can be seen on fresh surfaces. Microscopically the rock was found to contain biotite, hornblende, quartz, and andesine plagioclase, with subordinate amounts of augite, orthoclase, magnetite, and apatite.

The age of this intrusive mass can not be closely determined, but as it cuts the youngest sedimentary beds which are included in the Upper Jurassic Naknek formation it is post-Jurassic. As the sedimentary beds are not flexed at the contact of the igneous rock, there must have been a heavy load of overlying sediments at the time of the intrusion. This assumption is further borne out by the coarsely crystalline nature of the igneous rock itself, which indicates slow cooling at considerable depth. Subsequent to the intrusion a long time must have elapsed to permit the removal of the overlying sediments, for at present the igneous rock is well exposed, forming high, rugged mountains. Glacial cirques are cut into the quartz diorite at the heads of the valleys in several places where the streams and ice have cut through the bordering sedimentary beds.

The intrusive mass trends a little northwest and is thus nearly transverse to the structural trend of the sedimentary rocks. At Portage Bay the Bear Creek-Salmon Creek anticline plunges toward Cape Igvak, and at Wide Bay the Wide Bay anticline also plunges toward the cape, forming a low point or saddle between the two parts of the anticline, and the intrusive body of quartz diorite cuts across the saddle. From the description of the geologic struc-



GEOLOGIC SKETCH MAP OF WIDE BAY AND VICINITY.



GEOLOGIC SKETCH MAP SHOWING ELEPHANT MOUNTAIN ANTICLINE AND VICINITY.

ture in the Cold Bay region (p. 195) it is seen that nowhere else have the axes of the anticlines been folded to form a saddle, and it may be significant that the intrusive mass is associated with the only known fold of this kind. The interpretation of the relation depends to a large extent upon the time relations of the period of folding and the period of deformation. The geologic record is far from complete, and the most that can be certainly stated with present knowledge is that both the intrusion and the folding occurred after the deposition of the Upper Jurassic sediments, which are cut by the intrusive mass and are involved in the folds. However, from the field relations it seems probable that the period of folding preceded the period of intrusion, and the location of the intrusive mass in the saddle is believed to have no genetic relation with the saddle.

A dike at Portage Bay cuts both the Shelikof and Naknek formations and is described as diorite porphyry heavily impregnated with pyrite. This dike is undoubtedly an offshoot from the intrusive mass described above. Basaltic dikes cut the Shelikof formation and the Upper Triassic limestones at Cold Bay. Some of the basalts may be lava flows interbedded with the Triassic limestone.

There are nearly thirty active or recently active volcanoes[17] on the Alaska Peninsula and the Aleutian Islands, and probably many more than that have been long extinct and subsequently dissected. The Cold Bay district presents no exception to the history of volcanic activity so characteristic of the rest of the peninsula. It contains no volcanoes that are active now, but former activity has left a clear record in the district. The most recently active volcano is Mount Peulik (see Pl. X), which is the most prominent topographic feature on this part of the peninsula, rising to a height of 4,800 feet, and it has so recently become extinct that it still retains its conical shape. The present volcano stands on the rim of an older crater which is drained by Hot Springs Creek, through a deep, narrow gorge cut in its rim. In the center of the crater rises a large purplish cone-shaped hill, which represents either the core of the ancient volcano or a more recent subsidiary cone. The walls of the crater are composed of upturned shale, conglomerate, and sandstone, overlain by basaltic lava flows. Except for the Hot Springs Creek gorge the rim of the crater is intact and rises to a height of 2,000 feet, inclosing a great circular basin 2 miles across, in the middle of which the dull-purple cone rises as high as the rim. Basaltic lava flows have been poured out in all directions from the craters of both the ancient volcano and the present Mount Peulik.

[17] Waring, G. A., Mineral springs of Alaska: U. S. Geol. Survey Water-Supply Paper 418, pl. 1, 1917.

North of Mount Peulik three low hills rise out of Lake Becharof and are connected to the shore by a narrow strip of land which is very low and swampy. These hills are prominent, not because of their great height but because they rise directly out of the water and because they contrast strongly with the low rolling topography adjacent to the shores of the lake. They are the remnants of a volcanic cone which has been dissected by erosion. The middle hill of the three is composed of diorite porphyry and represents the core of the ancient volcano. The hill on the south side of the volcanic neck is composed of cemented ash and cinders, roughly stratified and dipping away from the core. The smaller hill, north of the other two, was not visited, as its existence was not known until the group was seen from the southwest, but it is doubtless also made up of cemented cinders and ash representing another flank of the cinder cone.

The Kejulik Mountains trend northeast and are about 15 miles northwest of Cold Bay. Near their junction with the coastal mountains is Mount Mageik, the active volcano nearest to Cold Bay. Great volumes of steam ascending about 3,500 feet in the air are frequently emitted by this volcano. From favorable places near the head of Cold Bay can be seen other volcanoes giving off quantities of steam, but these are all farther northeast along the peninsula, in the vicinity of Mount Katmai. The Kejulik Mountains have a very rugged appearance, showing numerous jagged peaks of igneous rock and lava-capped ridges. No distinct craters can be observed from the valley, but the extent of the lavas that can be seen on many of the ridges suggests that lava must have been poured out from several openings. The Kejulik Mountains, if extended southwestward, would include Mount Peulik, and the dissected volcano lying north of Mount Peulik and other volcanic areas on the peninsula southwest of Mount Peulik would line up with this same general trend. A line of weakness appears to exist along the peninsula in this region, localizing the volcanic activity, and there must be a genetic relation between the different volcanic areas.

An extensive area of granite was reported to occur on the west shore of the south arm of Becharof Lake near the mouth of Featherly Creek. An outcrop of arkose was found 2 or 3 miles from the mouth of Featherly Creek in the creek bed, and it is believed that this arkose was mistaken for a granite, as it was classed as an arkose with some hesitation in the field. Microscopic determination, however, leaves no doubt as to its sedimentary origin. The topography and structure of the area adjacent to Becharof Lake do not suggest the presence of granitic rocks. The south arm of the lake lies in a syncline, and normally the younger rocks should be exposed near the axis of a syncline, rather than the basement rocks

upon which they were deposited. If the granite had been intruded subsequent to the deposition of the Jurassic sediments, later erosion that would have uncovered it would have cut away the soft sandstone and shale much faster than the granite, which would have been left as rugged peaks and elevated masses. Such forms do not occur in the Featherly Creek region, where the lower part of Featherly Creek flows through a low, slightly rolling country, such as would be produced by the physiographic development of the region in the absence of any intrusive masses.

The igneous rocks in the area southwest of Wide Bay, as in most other parts of the Alaska Peninsula, are chiefly of volcanic origin and are composed of andesitic and basaltic flows, tuff, and volcanic breccia. Dikes, sills, and laccolithic intrusions are also of frequent occurrence throughout the region.

The most conspicuous mass of igneous rocks mapped in the region extends from the southwest end of Lower Ugashik Lake to Aniakchak Crater, in the central part of the peninsula. The lower chain of mountains west of the main Aleutian Range is composed entirely of this central igneous mass. In the lowlands that border the Bering Sea and extend westward from these igneous mountains is a small isolated group of mountains west of Ugashik Lakes. This group was not visited, but from its physiographic expression and its position in respect to the known igneous rocks it is probably part of the same mass. Specimens collected from various parts of the large igneous mass have been determined to be andesite. Segregations of red jasper in the form of stringers and small irregular veins occur abundantly in these rocks, and crystal aggregates of stilbite were found scattered over the surface of some of the mountains. The entire mass of andesite is of a light-red or pink color, which, together with the rugged crests of the mountains, distinguishes the igneous rocks from the dark-gray sedimentary rocks of the region. From a distance the igneous rocks in several localities appear to be rudely stratified, with a strike and dip accordant with those of the contiguous sedimentary rocks.

The core of the main range along the Pacific coast between Wide and Chignik bays consists of large masses of andesite, quartz diorite, and basalt. The eastern boundaries of these igneous masses were not mapped, but volcanic rocks of various types are reported to occur along the coast from Wide Bay to Chiginagak Bay. At the head of the valley southwest of Wide Bay is a large mountain composed almost entirely of dark columnar basalt, into which a small glacier has cut deeply, forming a steep wall in which the basalt columns are well exposed. They stand vertically, are about 1 foot in diameter, and reach 20 feet or more in length.

The sides of Mount Chiginagak appear to be partly covered with recent lava flows, which are reported to extend to sea level at the head of Chiginagak Bay. The base of the volcano on the west side is formed by sedimentary rocks. A narrow strip of quartz diorite about 2 miles wide extends from the northwest side of Mount Chiginagak and merges into the central igneous area. On the south is a belt of sedimentary rocks, probably Upper Jurassic, which extends toward the coast. These rocks are intruded northwest of Amber Bay by a large mass of igneous rocks. Only the western border of this area was examined, but many mountains with the sharp crests characteristic of igneous rocks were seen toward the east. The specimens examined from this area range in character from basalt to diorite.

The largest area of igneous rocks in the region is found west of Aniakchak and Kujulik bays, where at least 200 square miles is covered to an unknown depth by andesitic flows and coarse volcanic breccia or agglomerate. This area extends about 16 miles up Aniakchak River and laterally from a point 2 miles north of the river southwestward to the northern entrance of Chignik Bay. The area narrows toward the southwest end of Kujulik Bay but includes parts of the peninsulas between Amber, Aniakchak, Kujulik, and Hook bays. The physical character and texture of the rocks vary somewhat throughout the area, but they are all varieties of hornblende andesite and pyroxene andesite. The greater part of this igneous breccia is in the form of angular fragments cemented together by a matrix of similar composition but in part differing in color from the fragments. Volcanic tuff and breccia of this type occur in many parts of the Alaska Peninsula. As described by Atwood,[18]

> The fragments included in this tuff range up to 20 feet in diameter; commonly their dimensions vary from 3 to 6 feet. Individual blocks display the darker shades of red, green, and gray. Some of the blocks are distinctly black and all of them show a scoriaceous texture. The tuff is poorly stratified but appears to have been in part, at least, laid down in water.

This description fits the rocks in the region west of Aniakchak and Kujulik bays except where they are less noticeably scoriaceous and more massive. Quartz occurs at places in the form of thin stringers through the tuff. At one locality west of the central shore line of Kujulik Bay a quartz vein about 3 feet wide was noted. Silicified tree trunks 2½ feet in diameter are embedded in the igneous material north of the long spit on the shore of Kujulik Bay. Smaller fragments of silicified wood were found on the mountains west of the bay, where the volcanic rocks are at least 1,000 feet thick. A high pinnacled mountain about 5 miles southeast of Aniakchak Crater does not consist of the brecciated material but is composed of massive

[18] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, p. 70, 1911.

hornblende andesite. This mountain is probably older than the flows.

Nearly all the igneous masses southwest of Wide Bay are either intruded through the Tertiary rocks or have flowed out over their surface. Similar igneous rocks in other parts of the peninsula have been considered chiefly of late Eocene or Miocene age. At several localities, especially at the head of the valley southwest of Wide Bay, the intrusive masses are found only in Upper Jurassic sedimentary rocks and may possibly be older than Tertiary, but their similarity to known Tertiary intrusive rocks and, in one place, their connection with such rocks make it probable that they are of the same age. Volcanic activity has undoubtedly been continuous on the Alaska Peninsula since early Tertiary time.

STRUCTURE.

GENERAL FEATURES.

The structure in the Cold Bay district is simple and is characterized by large features that can be easily followed in the mountainous part of the district. The sedimentary beds have a northeast strike and a dominant northwest dip, but this general attitude is interrupted by at least two and probably three lines of folds and faults that are approximately parallel to one another and to the coast. One line of folding extends through Wide Bay and Portage Bay to Rex Creek, a tributary of Dry Bay, and is continued northeastward through Cold Bay and an unknown distance northeast of Cold Bay by a fault. The second line of folding is a well-developed anticline lying 8 to 15 miles inland and extending southwestward from Mount Burls. Between these two anticlinal folds lies a synclinal trough extending northeastward through the southern arm of Becharof Lake and possibly into the Kejulik Valley. (See Pl. IX.) These folds have been fully described by Capps,[19] but a brief description of the folds will be given here in order that the reader may have a general knowledge of the structure of the region and its relation to adjacent regions.

The line of folding and faulting nearest the coast has been divided into three parts called the Wide Bay anticline, the Bear Creek-Salmon Creek anticline, and the Dry Creek fault. The Wide Bay anticline (see Pl. XI) is described in detail on pages 201–202.

At Portage Bay the extension of the Wide Bay line of folding is seen as a plunging anticline that rises on the east side of the bay and spreads out within a short distance to form the Bear Creek-Salmon Creek anticline. This anticline, which is conspicuous and well developed, extends from Portage Bay across the headwaters of Bear

---

[19] Capps, S. R., The Cold Bay district: U. S. Geol. Survey Bull. 739, pp. 109–116, 1922.

Creek and Salmon Creek and gradually flattens out near Rex Creek, a tributary of Dry Bay. The southeast flank of the anticline dips only 3° to 5°, but the northwest flank dips about 16°. The sediments exposed over the fold consist of sandy shale of lower Shelikof age near the crest and progressively younger beds on the flanks, the Naknek formation cropping out far down on the northwest flank. The Shelikof is the only known oil-bearing formation in this region, and it is deeply cut by erosion on the crest of the anticline. The lower 1,000 feet of the Shelikof formation at Wide Bay is made up predominantly of shale. Little is known of the distribution of the formations below the Shelikof, as it was deposited on an eroded surface. At Cold Bay the Shelikof is underlain by Lower (?) Jurassic sediments, so far as known, and at Wide Bay it is underlain by the Kialagvik formation, of Middle (?) Jurassic age. The areal extent of these formations and the possibility that either one of them contains oil are not definitely known, but no oil has yet been found in the formations underlying the Shelikof in the Cold Bay district. The Bear Creek-Salmon Creek anticline flattens out northeast of Rex Creek and is succeeded near the head of Trail Creek by the Dry Creek fault. This fault cuts across the head of Cold Bay, and two parallel faults appear on the northeast side of the bay. The south side of the fault has moved down relative to the north side, and several outliers of Naknek rocks have been formed. The maximum displacement is believed to occur on the west side of Cold Bay near the mouth of Teresa Creek and is estimated by Capps to be 2,500 feet. The fault continues an unknown distance northeast of Cold Bay.

The next structural feature northwest of the main line of deformation just described is the Becharof Lake syncline. (See fig. 2, p. 202.) This is a broad, open fold extending southwestward from the south arm of Becharof Lake and possibly northeastward into the Kejulik Valley. The syncline is asymmetric, having dips averaging 15° on its southeast flank and only 8° on its northwest flank. On the west shore of the south arm of Becharof Lake, in the trough of the syncline, a series of shale beds that contain numerous fossiliferous limy concretions and are estimated to be over 1,000 feet thick may represent the highest Naknek beds known in the region. The relation between this shale and the sandstone and conglomerate that crop out around Mount Peulik is not known, but if the relation is not complicated by concealed faulting, the sandstone and conglomerate with some shale exposed around Mount Peulik must be the youngest sediments that crop out in the Cold Bay region and may be either the highest Naknek or some undetermined younger formation.

The Ugashik Creek anticline lies northwest of the Becharof Lake syncline and extends southwestward from Mount Burls. This anticline shows its maximum development between Mount Lee and Mount Demian on the east and the old crater of Mount Peulik on the west, where the strata are arched into a dome that is locally called the Pearl Creek dome. Southwestward from the Pearl Creek dome the anticlinal fold flattens, and in the vicinity of Deer Creek it disappears entirely. The dome is slightly asymmetric, and the axial plane is inclined to the southeast, in the same direction as the other folds in the region. The southeast flank has a maximum dip of about 30°, but dips as high as 69° have been recorded on the northwest flank. The rocks exposed over the dome belong to the Naknek formation. Between the crest of the dome and Mount Peulik about 4,000 feet of Naknek sediments are represented. Between the crest of the dome and the axis of the Becharof Lake syncline, to the southeast, about 5,000 feet of Naknek sediments are well exposed. (See fig. 2.)

Owing to the great lateral variation in the sediments it was not possible to determine the exact position in the Naknek formation of the rocks exposed on the crest of the dome, but they seem to belong in the lower part of the formation, an inference which means that the Shelikof formation is probably covered at the crest of the dome by only 200 or 300 feet of Naknek sediments.

The Pearl Creek dome, which is now being exploited, offers more promise of containing commercial quantities of petroleum than any other structural feature in the Cold Bay field. The main features that make this dome the most advantageous place to drill are the well-developed closed structure, which is so favorable to the retention of petroleum, and the presence of the unexposed Shelikof formation, comprising a thick series of sandstone and interbedded shale that constitute potential oil-bearing beds, overlain by 1,000 feet of shale that forms an impervious cap rock.

A less important feature of the structure of the region is the upturning of the strata around the old crater of Mount Peulik. This phenomenon is most apparent from points within the crater itself, where erosion has cut stream valleys around the periphery of the inner cone, exposing the sediments that were cut through by the volcanic neck. Around the southern half of the crater the strata dip from 8° to 18° away from the volcano; around the northern half the sedimentary rocks are not exposed. This upturning is believed to be very local, as the dip of the sedimentary beds where they crop out beyond the lava flows does not show any definite relation to the volcano. It is probable that the volcano broke through near the crest of an anticline and that many of the apparently inconsistent dips are the combined result of a change in direction of dip at the

crest of the anticline and the secondary local upturning of the sedimentary beds around Mount Peulik.

The general structure of the sedimentary rocks southwest of the Cold Bay district is monoclinal, with a prevailing southwest strike and dips of 4°–42° NW. A narrow asymmetric fold is superimposed upon the monocline 10 miles southwest of the lower end of King Salmon Lake. This fold is local and can be followed only a few miles across a high ridge, although it may continue for a short distance in the valley north of the ridge. The strike of this small anticline is N. 40° E. The southeast flank is about half a mile wide and dips 4°–6° SE. The northwest flank extends about 2 miles from the axis and dips 8°–15° NW. The upper strata exposed along the anticline belong to the Tertiary formation, which is at least 2,000 feet thick at this locality. The underlying beds are probably Upper Jurassic. Unless a detailed study reveals more favorable structural and stratigraphic features or indications of oil that were overlooked in a hastily made reconnaissance, the possibility of obtaining oil within moderate drilling depth on this anticline is small.

The crest of a broad anticline extends northeastward across the divide from the north side of the upper valley of Lava Creek to the headwaters of Cinder Creek. (See Pl. XII.) This structural feature, which has been named the Elephant Mountain anticline, is probably part of the main anticlinal fold of the Aleutian Range. A description of it is given on page 204.

AREA NORTH OF MOUNT PEULIK.

The investigation around the north side of Mount Peulik in 1922 (see Pl. X) did not supply much information additional to that obtained by Capps in 1921, as the greater part of the area is masked by lava flows, glacial débris, or mountain outwash, making it impossible to determine the character and attitude of the sedimentary beds. Immediately north of Mount Burls the Ugashik Creek anticline flattens out abruptly and merges into the northwest limb of the Becharof Lake syncline. Observations on Featherly Creek showed that the syncline extends that far, although somewhat flattened, owing to the disappearance of the anticline. The maximum dip observed on the northwest flank of the syncline north of the end of the Ugashik Creek anticline is 10°. One erratic dip of due north was seen in the bank of the creek that marks the eastern contact of the lava with the sediments and flows northward into the main part of Becharof Lake. No other consolidated sedimentary rocks were seen north of Mount Peulik in an area of about 75 square miles, which is covered by lava flows and glacial débris. West of Mount

Peulik the consolidated sediments are covered by an unknown thickness of mountain outwash composed of basaltic boulders. Outcrops of consolidated sedimentary rocks reappear beneath the lavas due west of the old crater of Mount Peulik. The outcrops are very small, and only one was found to have the dominant northwestward dip. Southwest of the crater several outcrops show a northeast strike but dip to the southeast. These local observations suggest an anticlinal fold with a northeasterly trend and with flanks dipping 23° NW. and 15° SE. Such an anticline, if it really exists, may have been formed by the intrusion of the igneous core of the older volcano, with which it is so closely connected. The force of this intrusion complicated the system of folding by bowing up the strata immediately around the contact, and then the outpouring of lava effectively concealed the sedimentary rocks. On the east side of Mount Peulik, near the edge of the lava flow, the sedimentary beds dip southeast, forming the limb of the Becharof Lake syncline, but southwest of Mount Peulik the sedimentary beds in one outcrop dip northwest. If the dominant dip in the region is northwesterly, as it seems to be, the sedimentary beds of the northwest limb of the Becharof Lake syncline would naturally be expected to flatten out and then to dip to the northwest, in conformity with the major structural trend, thus forming an anticline. The northeastward extent of such an anticline can not be determined, but it may extend out into Becharof Lake and across Severson Peninsula, where the rocks are said to have a northerly dip. The other anticlinal folds in the Cold Bay district have gently dipping southeastern flanks and more steeply dipping northwest flanks, and the scanty evidence would indicate that the supposed Mount Peulik anticline is no exception. A close examination of Severson Peninsula would be necessary to verify the existence of this anticline. Even if it exists it is not likely to prove of economic importance.

KEJULIK VALLEY.

The sedimentary beds in the Kejulik Valley (see Pl. IX) have not been folded into definite anticlines and synclines, like the beds in the areas farther southwest just described. The dominant structural feature is a northwestward-dipping monocline showing minor variations in the amount of dip. The highest dip recorded is 25°, and from this dip the angle decreases with minor variations until the beds become horizontal, and still farther northwest the strata are turned up the other way, giving low dips to the southeast, away from the Kejulik Mountains. The consistent and uniform dips and well-developed folds that occur southwest of Cold Bay and Becharof Lake do not persist into the Kejulik Valley. It is possible that the Becharof Lake syncline is a persistent structural feature extend-

ing along the east side of the south arm of Becharof Lake and thence into the Kejulik Valley. If so the monocline which occupies nearly the entire valley represents the south limb of the syncline.

The area of monoclinal dip may be divided into four zones—two of steeper dips and two of relatively low dips. Steep dips occur at the extreme southeast edge of the valley, in the high hills immediately north of the head of Cold Bay. A dip of 23° was recorded at the contact of the Shelikof and Naknek formations at the crest of one of these hills. The first zone of steep dips is about 2½ miles wide, from the hills at the head of Portage Creek to a line extending from the forks of Margaret Creek to the head of Albert Creek. Within this zone the dips gradually decrease from 23° on the southeast side to 8° at the northwest. This low dip is arbitrarily assumed to mark the beginning of the first zone of flatter dip, which is a little over a mile wide. About 2½ miles from the head of Albert Creek the dip increases rather abruptly from 10° to 22°, thus marking the end of the zone of low dips. The steep dip of 22° does not persist and gradually decreases to 8° or 9° within 5 miles, so that the second zone of relatively steep dips ends at a line drawn N. 65° E. from the junction of the East Fork with Kejulik River. Northwest of this line the dips are all low, averaging about 7° in a zone about 4 miles wide. Kejulik River flows through this zone. This northwestern limit of the valley and of the monocline is marked by an upturning of the strata against the Kejulik Mountains. This upturning is particularly noticeable at the head of the valley. This resulting trough may represent the extension of the Becharof Lake syncline, or it may be genetically related to the forces that caused the intrusion of the igneous rock into the Kejulik Mountains. Future investigation may determine the exact relation of the sediments to the igneous rock, but so much low land with no rock outcrops intervenes between Becharof Lake and the upper part of the Kejulik Valley that it has not been possible to trace the rock structure between the two areas. The gradual regional flattening of the dip from the southeast toward the Kejulik Mountains would suggest that the reversal of the dip is a structural feature which is not primarily related to the mountains but which may have been slightly modified by the intrusion of the igneous rocks. The syncline may represent the extension of the Becharof Lake syncline, and the upturning of the strata against the mountains may represent one limb of an anticline along which the igneous rocks were intruded and which might be extended to join the anticline supposed to underlie Mount Peulik. This hypothesis is supported by observations made farther northeast on the peninsula by Spurr,[20] who says:

[20] Spurr, J. E., A reconnaissance in southwestern Alaska: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 146, 233, 1900.

On each side of the chain of volcanoes which form the axis of the range the stratified rocks dip away very gently and are slightly undulating. * * * The line of volcanoes is along a belt where the lava has broken up through the sedimentary Jurassic rocks, tilting these very gently on both sides away from the mass.

The zones of low dip and of relatively steep dip do not form large, pronounced structural features but simply show minor variations of the monoclinal dip. The strike of the rocks would carry these zones across the coastal mountains into an area not covered by this report, and within the valley the evidence for some of the zones is based upon only a few outcrops. Owing to scattered erratic dips and the grading of one zone into another, the placing of the border lines of each zone is somewhat arbitrary, but it is believed that the descriptions given essentially represent the conditions existing in the valley.

WIDE BAY ANTICLINE.

The Wide Bay anticline (see Pl. XI) is a fold of large dimensions, but unfortunately the greater part of its crest lies beneath the waters of the bay, and the details of the anticline can not be studied. This anticline is a continuation of the Bear Creek-Salmon Creek anticline. which extends northwestward from Portage Bay. On the cape between Portage and Wide bays the line of folding is interrupted by a large igneous intrusion. From the northeast end of Wide Bay the anticline extends to the head of the valley at the southwest end of the bay. The southeast flank is represented by the group of islands and point of land partly inclosing the bay. The northwest flank is from 5 to 8 miles wide and is formed by the westward-dipping beds in the mountains on the mainland. The anticline is terminated at the head of the valley southwest of the bay by large masses of igneous rocks. Some of the igneous rocks, especially the basalt, may be only surface flows, but a large intrusion of quartz diorite near this locality is probably deep seated. Farther southwest the rocks were not examined, but it is quite likely that the anticline reappears, inasmuch as the crest of the Aleutian Range is structurally a great anticline or anticlinorium. However, the mountainous country between Wide and Amber bays is very rugged and difficult of access.

The lowest beds exposed on the Wide Bay anticline are part of the Kialagvik formation, of Middle (?) Jurassic age. These beds are exposed from the banks and bluff close to the beach southwest of Lee Creek to and beyond the head of the bay. The thickness of this formation and the character and age of the underlying beds are not known. The Shelikof formation, of Upper Jurassic age, overlies the Kialagvik formation unconformably. The unconformity shows that erosion and deformation of the Middle (?) Jurassic rocks occurred before the Upper Jurassic sediments were deposited.

If folding took place before Upper Jurassic time it may have been slight and local, but it would have significance in the accumulation of oil, provided oil is present beneath the Wide Bay anticline. The beds of the Kialagvik formation for half a mile northeast along the beach from the mouth of Lee Creek can be seen at low tide striking out in the bay at an angle of nearly 90° to the axis of the Wide Bay anticline. This unconformity does not appear so well marked elsewhere, but other discordant dips were noted. Only at the extreme southwest end of the bay do the Middle (?) Jurassic beds conform in strike and dip to the overlying Shelikof formation. At other localities the lower beds are either horizontal or are discordant with the Upper Jurassic beds. The apparent irregularities of the lower beds, which in places strike transverse to the axis of the Wide Bay anticline, may be of such magnitude as to form suitable reservoirs for oil, but care should be taken in selecting a well site.

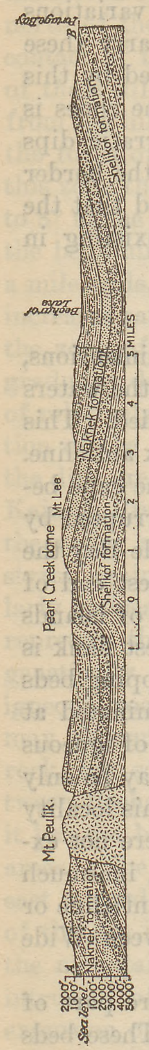


FIGURE 2.—Structure section from Mount Peulik to Portage Bay, along line *A–B*, Plate X.

The exact location of the axis of the Wide Bay anticline can not be determined, as its crest is covered by the bay or the alluvium in the valley. However, the axis is probably closer to the shore of the mainland than to the islands. At several places along the northwest side of the bay the beds are nearly horizontal. The beds in the islands dip 6°–24° SE. and are probably well down on the southeast flank of the anticline.

UGASHIK CREEK ANTICLINE.

The most promising fold for the accumulation of oil in commercial quantities in this region is the Ugashik Creek anticline. (See Pl. X and fig. 2.) This anticline extends from Burlis Mountain, near the source of Featherly Creek, southwestward about 16 miles to Deer Creek. It lies within the northeastern part of the drainage basin of Upper Ugashik Lake and is from 8 to 12 miles inland from Portage and Wide bays. The northeast end of the anticline, which is now being drilled for oil, is a well-developed dome, referred to above as the Pearl Creek dome, on which there are several seepages and two patches of oil residue. Special attention was given during the recent investigation to the southwest end of the anticline. Where the fold crosses Crooked Creek both limbs dip 12°, but the dips become gradually less toward the southwest, until at

Deer Creek the anticline dies out into a monocline with only northwest dips.

The axes of the Becharof Lake syncline and the Ugashik Creek anticline, which are about 5 miles apart between upper Becharof Lake and the Pearl Creek dome, converge in the vicinity of Moore Creek until they are only 3,000 feet apart. Where the synclinal axis approaches the anticline a thrust fault of considerable displacement occurs along the crest of the anticline and parallel to the axis of the syncline. The beds on the northwest flank of the anticline at Moore Creek are undisturbed and dip 4° NW. The overthrust beds, which are composed of conglomerate and arkosic sandstone, dip 19°–35° SE. The angle of the fault plane is about 45°, which would project the fault down the southeast flank, leaving the crest of the anticline undisturbed at a moderate depth. However, the area in which oil could accumulate on the southeast flank is very small, whereas the dips on the northwest flank are gentle but extend at least to Ugashik Lake. The fault was traced about 2 miles. Southwest of Moore Creek the syncline swings to the south, toward Deer Mountain. The anticline continues as far as Deer Creek, but it is more in the nature of a terrace than a well-developed fold.

Rocks of the Naknek formation extend over the entire area of the Ugashik Creek anticline except near the northeast end, where igneous rocks occupy a small area in the vicinity of Mount Peulik. Toward the southwest end of the anticline the surface rocks are composed of conglomerate, arkosic sandstone, and thin beds of shale, part of which represent the conglomerate at the base of the Naknek formation. The basal conglomerate of the Naknek is exceedingly variable in thickness. At Cold Bay it is only 70 feet thick, but along Lee Creek at Wide Bay the member is represented by at least 3,000 feet of conglomerate and arkosic and pebbly sandstone. In the valley of Deer Creek near Deer Mountain 2,000 feet of rather massive conglomerate is exposed. Where the anticline crosses Ugashik Mountain the beds dip southwest, forming part of the Pearl Creek dome. These beds are not exposed on the anticline southwest of the mountain, although the altitude is no greater than at Ugashik Creek. Hence deeper drilling would propably be necessary on the anticline to the southwest than on the dome.

The wells that are now being drilled at the most favorable sites on the dome should demonstrate whether the southwestern part of the Ugashik Creek anticline is worthy of a test by drilling. By means of a well log and a detailed stratigraphic study of the strata in Ugashik Mountain and along the anticline farther southwest, with the thickening of the Naknek conglomerate in mind, it should be

possible to make fairly accurate estimates of the depth to the oil horizon at different localities.

ELEPHANT MOUNTAIN ANTICLINE.

The Elephant Mountain anticline (see Pl. XII) is the only large anticline in the region southwest of Wide Bay. It lies close to the divide between the Pacific Ocean and Bering Sea drainage and extends from the north bank of upper Lava Creek northeastward across Elephant Mountain to the headwaters of Cinder Creek. The country beyond Lava Creek in the direction of the anticline is very rugged, and some of the mountains are composed of igneous rocks. Several intrusive dikes and sills occur along the crest and on the limbs of the anticline. The extreme outer flanks of the anticline on Lava Creek and the middle part of Aniakchak River dip 18° to 45° and are 12 miles apart. Both flanks can be seen from Pinnacle Mountain. Along the axis of the main anticline the dips are gentle and the beds are folded into several small anticlines and synclines whose axes roughly parallel the main line of folding. These superposed folds are difficult to follow across the rugged country. The axis of one of the small anticlines is nearly parallel with the valley of Wiggly Creek, and the flanks of this anticline are narrow, with dips of 2° to 6°.

The main line of folding is probably part of the principal anticline of the Aleutian Range. This structural feature, although broken in several places, extends through the greater part of the Alaska Peninsula. In the area between Lava Creek and Aniakchak Crater the anticline rises and flattens out. The oldest rocks exposed on the crest of the anticline are part of the Naknek formation. These beds crop out in a small area on the north side of Lava Creek valley and in several mountains toward the southwest, including the south side of the crater rim. The surface rocks over the greater part of the Elephant Mountain anticline are Tertiary.

FAULTS.

The deformation in the Cold Bay district has not been marked by severe faulting. The only recorded fault of any notable size is the one described by Capps, which crosses the head of Cold Bay. This fault has a maximum displacement of 2,500 feet on the west shore of Cold Bay, but the throw seems to decrease both southwest and northeast from that point. The southwestward extent of the fault is not known, but it extends at least to the head of Dry Creek; northeast of Cold Bay the fault has not been followed. A few small faults were also mapped southwest of Cold Bay, but all of them are of local extent. North of Cold Bay, in the Kejulik Valley, a few

small fault planes were seen near the point of upturning of the sediments against the Kejulik Mountains, but nowhere is there much if any displacement along these faults. In other places in the valley erratic dips were seen that may represent local faulting, but no fault planes were seen in conjunction with them. North of Mount Peulik the sedimentary rocks do not crop out and if faults are present they can not be seen on the surface.

MINERAL RESOURCES.

PETROLEUM.

The presence of petroleum in the sedimentary rocks of the Alaska Peninsula is disclosed by seepages that have been reported at several places from time to time. The earliest reference to petroleum on the peninsula was made by Davidson[21] and Dall[22] in 1869, when they reported a seepage "near Katmai Bay." Subsequently seepages were seen in the Cold Bay region and have been reported around Aniakchak Bay and Chignik. Most of the seepages reported have been in the region that has become popularly known as the Cold Bay field, where patches of residue and seepages have been seen at several places.

The petroleum seepages in the Cold Bay field have been described by Capps,[23] and the following descriptions are taken substantially from his report. The seepages are in two groups lying along the two lines of anticlinal folding. Several seepages have been reported along the Bear Creek-Salmon Creek anticline and near the extension of its axis at the head of Oil Creek. Two seepages occur on the Pearl Creek dome, a part of the Ugashik Creek anticline. (See fig. 2.) The largest seepage is found at the head of Oil Creek, in the East field, where oil, gas, and water emerge as a strong spring and the evaporation of the more volatile constituents of the oil has left a large area of a viscous black residue 1 to 6 feet thick. The flow of this seepage was estimated by Capps at about half a barrel of oil a day. On Oil Creek below the residue patch there are several seepages that yield a small flow of oil. Other seepages are reported from the South Fork of Rex Creek, and one each from upper Bear Creek and Salmon Creek. All these seepages are on the Bear Creek-Salmon Creek anticline, but they emerge from sandstone of the Shelikof formation well down on the flank of the fold.

Two residue patches occur on the Pearl Creek dome. One near the mouth of Barabara Creek on its north side is similar in size and

[21] Davidson, George, Coast Pilot of Alaska, 1869, p. 36.
[22] Dall, W. H., idem, p. 199.
[23] Capps, S. R., The Cold Bay district: U. S. Geol. Survey Bull. 739, pp. 107–109, 1922.

character to the patch on Oil Creek. The actual point of emergence of the oil could not be seen, but water running along a drainage line through the residue was covered with thick dark-brown oil. The other residue patch, which is somewhat smaller, lies in the valley of Pearl Creek about a mile northeast of the large patch. No oil was seen emerging from the rock, but a thick brown oil oozes from the residue and flows down the creek. The rocks underlying these two residue patches belong in the lower part of the Naknek formation. Other small seepages have been reported to occur in the valley of Pearl Creek.

No seepages have been reported to occur in the region around Mount Peulik, except at the Pearl Creek dome, and none were seen during the summer of 1922. In the Kejulik Valley also no oil seepages were seen, although some have been reported and a gas seepage was seen near the head of the East Fork of Kejulik River. The gas emerges at two places several hundred feet apart, both at the foot of a bluff on the edge of a narrow valley. The gas flows in a nearly continuous stream of bubbles and has built up a low mound around the orifice. Evidently considerable water is emitted with the gas, as the mound is composed of a soft mud surrounded by an otherwise dry valley floor and a small stream of water flows away from the seepage. The rocks forming the bluffs along the edge of the valley and underlying the valley belong in the lower part of the Naknek formation.

The Kejulik Valley has been frequently mentioned as an area possibly underlain by oil reservoirs. It is generally understood at the present time that the geologic structure most favorable for petroleum accumulation is that of an anticline or dome. Petroleum accumulations have also been formed, however, as the result of different physical features of the rocks themselves, and any petroleum accumulations that may exist in the sediments underlying the Kejulik Valley are most probably due to such features. A change in porosity due to a change in the coarseness of the sediments deposited, a variation in porosity due to a variation in the amount of cementing material, and the presence of lenticular bodies of sandstone are all features that may be of prime importance in their influence upon the localization and accumulation of petroleum. The change in porosity and the presence of lenses of sandstone are likely to be of more importance in sediments deposited in shallow water and near the shore, such as most of the sediments in the Cold Bay district. Sediments laid down near the shore are usually of coarser grain than those deposited farther out, but they may grade laterally into the finer-grained sediments without any distinct break, and where they do there is a gradual change in the effective porosity of the rock and in its effect upon permeating liquids and gases. Petroleum might

migrate through a loose, porous reservoir sand, but if that sand becomes dense and fine grained the petroleum can no longer migrate through it and will accumulate in the coarser part of the bed if it is inclosed in impervious sediments. The sediments in the Cold Bay district are known to differ greatly in different parts of the district, but it is impossible to predict just where the porosity has changed sufficiently to cause accumulation, and hence it is impossible to predict the location of reservoirs formed in this way.

The variation in the amount of cementing material may also be an important factor in determining the location and extent of an oil reservoir. A sandstone may be tightly cemented so that it contains little effective pore space, or a sandstone composed of grains of the same size may be very loosely cemented, thus having a high effective porosity. The first sandstone would not make a good reservoir, but the second one might make an excellent reservoir.

There are local variations in the degree of cementation within a sandstone bed, and this feature is of particular interest in considering the possibilities of oil accumulation on a monocline. The reason for the differential cementing is not well understood, but it unquestionably exists. In a tightly cemented sandstone the existing pore space may consist of voids so small that the rock is relatively impervious to migrating petroleum, owing to the high frictional and capillary resistance. In many places the tightly cemented parts of a sandstone are in the form of thin seams paralleling the bedding planes, but in other places they are arranged irregularly. A tightly cemented part may occur in such a position as to effect an accumulation of petroleum in the more porous sandstone lying along the dip below it, giving rise to what is known in the oil men's vernacular as a "spotty sand." The determination of the location of such areas is even more difficult than that of the lateral variation in the lithology of sandstone beds, so that this feature is of no assistance in predicting the oil possibilities of the Kejulik Valley.

The third feature that was mentioned above as having a possible influence on the accumulation of oil is the presence of lenticular bodies of sandstone. Such bodies are frequently deposited under shallow-water conditions, where shore currents and river currents may both be active in forming bars and deltas. The sand lenses may be thick bodies having a lateral extent of several miles, and if they are included within a shale member of the formation that contains organic matter in sufficient abundance to supply petroleum to the sandstone lenses, large accumulations may be formed. Several fields in the United States have produced petroleum from lenticular sands.

All three of the features above set forth are difficult of determination in advance of drilling, but all three may have a decided influence upon the accumulation of petroleum upon a monocline. The

rocks that crop out in the Kejulik Valley are largely of the Naknek formation and overlie the Shelikof formation, which is the oil-bearing formation in the other parts of the Cold Bay district. Although no oil seepages were seen in the valley it is reasonable to assume that the Shelikof formation, underlying an area 10 or 12 miles from the nearest known seepage, contains petroleum, which under the proper structural and physical conditions would form accumulations. In the Kejulik Valley there is no known structural feature of the types that are usually considered favorable for petroleum accumulations, but various conditions of sedimentation may have produced the same result. The dip of the strata carries the Shelikof formation to a considerable depth below the Naknek formation within a short distance, so that it is only close to the southeast side of the valley that the Shelikof formation lies near enough to the surface to be reached by the drill.

The flattening of dip of a monocline forms the structural feature known as a terrace. In the Pennsylvania, Ohio-Indiana, Oklahoma-Kansas, and many other fields petroleum has been obtained from terraces, but as commonly used the term "terrace" includes any minor flattening of the dip of a monocline, so that the presence of a terrace does not necessarily mean the presence of structure favorable to the accumulation of oil. Such an accumulation on a terrace involves many factors that make its prediction difficult. The effect of change in porosity and lenticular sands is the same as on a monocline. (See p. 207.) The degree of change of dip is the critical factor, as the oil accumulates at and immediately below the point where the inclination of the strata has changed sufficiently to prevent further migration. The change of dip necessary to offer such a barrier is dependent upon the character of the sand, the initial inclination of the monocline, the force behind the movement of the petroleum, and nearly all the other factors that influence migration. In general the closer the flattened beds approach to the horizontal or to a reversed dip the greater the barrier they offer to the further migration of petroleum. In sediments having a low dip a flattening of only a few degrees may furnish an effective barrier, whereas if the same sediments are steeply inclined they might have to flatten a great many degrees to make the change in dip effective as a barrier. In the Kejulik Valley the zone of flattened dips extending across the headwaters of Albert Creek has dips 12° to 15° flatter than the zone of steeper dips northwest of it. However, as the less steeply inclined sediments dip 8° to 10°, it is believed that the relative decrease in the amount of dip is insufficient to prevent the further migration of the petroleum. In conjunction with the other factors that influence the accumulation of petroleum on a monocline the decrease in dip may have an importance that

can not now be seen or predicted. The fact that the dip may within a short distance carry the oil-bearing formations to a depth beyond reach of the drill must be emphasized. It is only near the southeastern edge of the valley that the Shelikof sandstones lie near enough to the surface to be reached by the drill, according to the common commercial practice, in which the limit of depth is 3,500 feet.

A few observations west of Mount Peulik suggest the existence of an anticline (see Pl. X), but its size and extent and even its existence can only be conjectured. Further, the igneous material involved in the formation of Mount Peulik is believed to have been ejected through a channel extending down through the crest of the anticline, and the heat and pressure exerted by this material may have severely metamorphosed the sediments and driven away any oil they may have contained. It is apparent that the area around Mount Peulik can not be recommended as probably containing available oil accumulations.

Oil seepages were reported to occur near the head of Moore Creek, but they were not found by members of Mr. Sargent's party. Along the fault at Moore Creek there are several springs giving off sulphur dioxide gas, which has a very characteristic odor and forms a white scum on the water. After the scum has been in contact with the air for some time it becomes black. The black substance has the appearance of an oil residue, but its physical properties differ, and it can easily be distinguished from oil residue by its peculiar odor and low viscosity. Several pools of water with an iridescent scum of iron oxide, which might be mistaken for oil, were seen in the small valleys in this general locality.

Oil seepages were not seen on the Elephant Mountain anticline, and none have been reported to occur along this fold, although there have been many reports of seepage west of Aniakchak Bay and on the cape between Aniakchak and Amber bays. Some of these supposed seepages were found to be films of iron oxide on pools of water and red iron stains on rocks. The seepages reported on the cape were not examined. The claims that have been staked in the Aniakchak district do not extend inland as far as the crest of the anticline, although some of the claims may include part of the southwest flank, where the dips are locally 45° SE. The lowest beds exposed on the anticline, those in the upper part of the Naknek formation, are probably thousands of feet above the supposed oil-bearing beds in the Cold Bay district. However, owing to the variable thickness of the strata, especially the conglomerate beds 60 miles to the northwest, it is impossible to estimate the depth to any particular horizon below the surface on the Elephant Mountain anticline. It is not improbable that there are oil-bearing rocks in the Upper Jurassic series that are

not known. The oil in the Cold Bay district is supposed to be derived from the Shelikof formation, but the exact horizon is unknown. A stratigraphic study of the region southwest of Aniakchak Crater, where Jurassic rocks are thought to be exposed, may furnish information regarding the succession beneath the Elephant Mountain anticline. Although at places on the anticline the structural conditions are favorable for the accumulation of oil, until indications are found or some of the reports of seepages in this general region are verified there is no reason to believe that this anticline contains commercial pools of oil. From present knowledge of the stratigraphy the possibility of such pools within drilling depth is relatively slight.

Oil seepages have been reported from the country west of Aniakchak Bay and east of the high mountains in the central part of the peninsula, and many claims have been staked there. It was learned in the field that most of the claims had been staked by one man. By far the greater number of claims are located in an area of igneous rocks, or in the valley of Aniakchak River, which is covered by the ejecta from the crater at the head of the valley. The consolidated rocks beneath the cinders are probably also of igneous origin, as the mountains on both sides of the lower part of the valley and several small outcrops within the valley consist of igneous rocks. Most of the rocks consist of volcanic tuff and breccia which have flowed out over the sedimentary rocks. The thickness of this volcanic material is not known but is thought to be several thousand feet. The thickness undoubtedly varies from place to place owing to the irregularities of the surface over which the material flowed. The volcanic center or vent was not located. A few small isolated blocks of sedimentary rocks, dipping very steeply beneath the igneous material, occur close to the beach at Aniakchak Bay.

Pools of stagnant water covered with an iridescent film of iron oxide were found in the area of igneous rocks near the localities where oil seepages were reported to occur. Oil seepages were also reported on the cape between Amber and Aniakchak bays. These seepages were not found, but sedimentary rocks of unknown age occupy part of the cape. If oil seepages occur in the general district they are more likely to be found in the vicinity of Amber Bay than in the area west of Aniakchak Bay.

Neither the Kejulik Valley nor the region north and west of Mount Peulik contains sufficiently well developed structural features of the types that are usually considered favorable for the accumulation of petroleum to be recommended as good places to drill wells. The sedimentary rocks of the Kejulik Valley have been folded to form a terrace, a structural form that has proved to be productive here and there in oil fields in the States, but in this valley the decrease in dip is not believed to be sufficient to form a reservoir

unless it is accompanied by other features, such as certain conditions of sedimentation and cementation that can not be predicted. If "spotty" sands are present in this area, no one drill hole would prove the nonexistence of an oil reservoir. Further, the oil-bearing Shelikof formation, except for a narrow belt at the southeast margin of the valley, is too deeply buried below the Naknek formation to be reached by the drill. In view of the expense of drilling in a new region and the number of holes that would be necessary to test the field thoroughly, the prospects of obtaining oil are not good enough to warrant drilling. The geologic structure in the region north and west of Mount Peulik is not as well known as the structure in the Kejulik Valley, as the bedrock is concealed by gravel and volcanic material, but some observations and the regional relations suggest the presence of an anticline extending northeastward through Mount Peulik, parallel to the trend of the other folds. The sedimentary rocks that crop out around the old crater of Mount Peulik are on the crest of this supposed anticline and are believed to be possibly high in the Naknek formation. The oil-bearing Shelikof sandstones may therefore be buried under several thousand feet of younger sediments, and even if the formation contains oil on this anticline it may lie beyond reach of the drill.

The future of the Cold Bay district depends very largely upon the result of the drilling on the Pearl Creek dome, as that is the most promising structural feature in the region, and the success or failure of the work there will probably govern the amount of later exploratory work.

The country southwest of Wide Bay, especially the Aniakchak district, is covered by large areas of igneous rocks, in which oil does not occur. The sedimentary rocks are mostly Tertiary and of a character that makes the possibility of the occurrence of oil in commercial quantities in them very slight. The anticlines are not as pronounced as those in the Cold Bay district, and those that were observed are small or possess unfavorable features.

COAL.

The distribution and economic possibilities of the coal in the Chignik Bay region are set forth by Atwood,[24] who gives detailed sections and describes the developments up to and including 1908. Since 1912 little coal has been mined, although some development work has been done, especially at a mine on Thompson Creek, where mine buildings were erected and a small bunker built on the beach. No coal, however, has been sold from this mine. The following

[24] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, pp. 104–105, 109–116, 1911.

description of the coal near Chignik is compiled by G. C. Martin from the account by Atwood, with slight modification.

GEOLOGIC AND AREAL OCCURRENCE.

The bituminous coal in the Chignik Bay region is of Upper Cretaceous age and belongs to the Chignik formation. The coal measures consist of sandstone, shale, and conglomerate that occur in the middle portion of the formation and are underlain and overlain by thin beds of sandstone and shale. The Upper Cretaceous (Chignik formation) in this region rests unconformably upon the Upper Jurassic (Naknek formation), but it is overlain conformably by rocks of Eocene age. This section is shown along Chignik River and along the shores of Chignik Lagoon.

The known extent of bituminous coal in this field does not exceed 15 square miles, but from the distribution of the coal outcrops and the general geologic structure in the field it is probable that coal underlies an area of 40 to 50 square miles.

A few thin lignite seams occur in the Tertiary rocks on the southwest side of Chignik Bay. The areal extent of these lignite seams is probably between 10 and 20 square miles, but the quality of this material is not such as to make it of economic value.

The developed coals are at Chignik River, Whalers Creek, Thompson River, and northwest of Hook Bay. Some detailed sections of these coals are given in the following paragraphs.

COAL BEDS.

Chignik River.—The coal bed that has been worked outcrops on the river bluff 3 miles above the head of Chignik Lagoon and has been traced inland for a little more than half a mile. At this locality it strikes N. 2° E. and dips 24° E. A section of the bed measured in the drift is as follows:

Section of Chignik River coal bed.

	Ft.	in.
Dry bone, with thin coal streaks		3
Coal		6
Coal and dirt		8
Coal	1	
Bony coal	1	5
Coal	1	4
	5	2

The roof, which is of shale with thin layers of coal overlain by sandstone, is very even. The floor, however, is not so regular, and the roll or swelling in it reduces the thickness of the bed at the end of the drift from 5 feet to 9 inches. It is possible that the roll, which

is known to be rather long, may be narrow, and that a short tunnel driven through it would discover the full thickness of the coal bed on the other side.

The coal is solid and bright and comes out in good-sized pieces. When used under a boiler it has to be stoked very frequently to keep it burning freely. It is a fairly satisfactory steaming coal when it is properly handled, but it makes a large amount of ash, and the fires have to be cleaned often. An analysis of this coal is given on page 218.

The Chignik River mine was formerly worked throughout the year by two men without machinery, the coal being undercut by hand and shot down. Coal outcrops appear at several other places on the north bank of Chignik River east of the mine, but the beds do not seem to be of as good grade as that at the mine and have not been worked.

Whalers Creek.—Whalers Creek is a small stream entering Chignik Lagoon from the north a short distance below the mouth of Chignik River. Coal is exposed for 600 feet along the northernmost of the three main branches of the creek, the exposure being along the strike of the coal measures, which outcrop at the coal mine on Chignik River. The strike of the coal is N. 5° E. and the dip is 22° E. The section of the coal is as follows:

Section of Whalers Creek coal bed.

	Ft.	in.
Shaly sandstone roof.		
1. Coaly shale		10
2. Shale		8
3. Coal	1	
4. Coaly shale		4
5. Sandy shale		7
6. Coal with slate partings	5	
7. Coaly shale		6
8. Sandstone	1	6
9. Coal	1	10
10. Shaly coal		1½
11. Coal	3	4
Sandy shale floor.		

The slope, which has been driven 130 feet on the coal, follows the lower part of the bed and includes the strata numbered 8 to 11 in the above section. The coal bed (Nos. 9 to 11) was sampled in the usual way and analyzed, with the result given on page 218 (laboratory No. 6955).

The coal is bright, black, and blocky, very much like that mined at Chignik River, but at this locality the section of the coal is better in that the partings are thin. A nearly vertical fault, about 500 feet downstream from the mine opening, probably cuts off the coal bed.

On the upstream side, about 40 feet from the opening, a vertical fault throws the coal down 6 feet, and 115 feet upstream from the mine another fault, which cuts off the coal, has been reported.

Although faults have disturbed the coal somewhat, there appears, nevertheless, to be a very considerable body of good coal available. The location of this coal favors shipment on small boats down Chignik Lagoon or by rail. A railway might be built across Chignik River a short distance above the mouth and thence across a lowland area to the head of Kuiukta Bay, where excellent harbor facilities are reported. The distance from Whalers Creek to the head of Kuiukta Bay by the proposed railway route is about 5 miles.

Coal has been reported to outcrop at several places high on the mountain slopes northeast of the outcrops of coal in Whalers Creek. The localities pointed out in the field by prospectors are along the general strike of the coal measures and presumably contain the same beds that are exposed elsewhere in the field.

Thompson Valley.—Thompson Valley lies northwest of the northern portion of Chignik Bay and is a broad, open, flat-bottomed valley, heading among the high mountains at least 10 miles from the beach. Coal is exposed on the northeastern slope 1¾ miles from the beach and 300 feet above the valley floor. The strike of the beds is N. 61° E. and the dip is 21° NW. Two workable coal beds are exposed for at least a mile, and their extent is probably much greater. Where the tributary streams to Thompson Valley cross these coals there are falls or cascades in their courses. The detailed measurements of these beds are given below:

Sections of coal beds in Thompson Valley.

Lower bed.

	Ft.	in.
Sandy shale roof.		
1. Coal	1	8
2. Shale parting		2
3. Coal	2	6
4. Coaly shale		4
5. Coal		5
6. Bone		1
7. Coal		2
Sandstone floor.		

Upper bed.

	Ft.	in.
Cross-bedded sandstone roof.		
1. Clay		2
2. Coal		4
3. Coaly shale		4
4. Shale		8
5. Coaly shale		4
6. Coal	1	
7. Clay parting		1

		Ft.	in.
8.	Coal	2	6
9.	Coaly shale		8
10.	Coal	4	
11.	Bone		8
12.	Coal		5
13.	Shale		5
14.	Bony coal		8

The analysis of a sample taken from the beds numbered 6, 8, and 10 in the foregoing section of the upper coal is given on page 218 (laboratory No. 6956).

A large body of good coal is available at this locality. The conditions for mining are favorable, and the space at the base of the bluff is ample for mine buildings and mine bunkers. The chief difficulty in the way of exploiting this coal is in making arrangements for shipping. The beach at the mouth of Thompson Valley is exposed to the severe storms from the Pacific Ocean. A railway from the valley to Chignik Lagoon could be easily built, for the route would be over a lowland area and not more than 9 miles in length. The conditions in Chignik Lagoon, however, are not favorable for loading large ocean-going vessels. Hence it would probably be necessary to continue the railway along the northwest shore of the lagoon and then by the same route as that from Whalers Creek to the head of Kuiukta Bay, as already described.

Hook Bay.—Hook Bay is in the northern part of the field examined. The coal in this vicinity occurs near the headwaters of the right-hand branch of the stream entering Hook Bay from the west and in the foothills of the main mountain range. The general strike of the beds is N. 11° E. and the dip 34° E. The section of the coal is as follows:

Section of Hook Bay coal bed.

		Ft.	in.
	Firm sandstone roof.		
1.	Coal	1	3
2.	Clay		8
3.	Coal		4
4.	Clay		7
5.	Coal	1	6½
6.	Clay parting		2
7.	Bony coal		5
8.	Coal	1	5½
9.	Bone		1
	Shale floor.		

Above this bed is an 8-foot bed of sandstone overlain by a thin layer of coal. Below the main bed of coal lies a 4-foot layer of shaly sandstone, underlain by a 3-foot bed of coal, in the middle of which is a 6-inch parting of shale. The exposures in the tunnel show the coal to be uniform in thickness and quality.

In sampling this bed a cut was made across Nos. 5 to 8, inclusive, in the above section. The analysis is given on page 218 (laboratory No. 6952).

The strike, so far as the beds could be examined, is uniform and appears to continue without notable break for at least half a mile to the northeast. The tunnel opening is 50 feet above the stream bottom, where there is space for mine buildings. At present there is a wagon road from Hook Bay to the coal croppings, along a stream bottom where the general gradient and space would be favorable to railway construction. Hook Bay is an excellent small harbor and is bordered by favorable sites for wharves and bunkers. The distance from the harbor to the coal is about 8 miles. Four claims were staked in this field, and development work was being done in 1908 under the auspices of the Alaska Peninsula Mining & Trading Co.

CHARACTER OF THE COAL.

The coal from the Chignik River mine is bright black and of medium hardness. It was worked out in lumps as much as 10 or 12 inches in diameter. The seam, as exposed late in the season of 1908, showed some crushing at the front wall and at the end of the tunnel. The section in the mine shows sufficient shale partings and bony streaks to indicate the general bedded structure of the coal, which corresponds to the general dip of the formations in that part of the field. The coal, when taken from the mine, was dumped upon a barge near the entrance of the tunnel and was unloaded from the barge and dumped into the coal bins at the cannery, where it was used. In the processes of handling the coal usually became broken into fragments, the largest 3 or 4 inches in diameter. This coal does not appear to slack badly. The best exposures in Whalers Creek are in a prospecting tunnel, where the coal seam is firm and the bedded structure pronounced, the structure being emphasized by certain shale partings. The coal is a dull black on the weathered surfaces but is bright in fresh exposures. The Thompson Valley exposures are only a little beneath the surface and not beyond the zone of weathering. This coal, however, is in a heavy firm bed, more resistant than the shale and sandstone associated with it, as is indicated by the rapids or falls where streams cross the coal seam.

In the short tunnel in the coal northwest from the head of Hook Bay the coal is in seams 18 inches or less in thickness, separated by thin beds of shale. These shale partings indicate the general bedded condition of the sediments and correspond with the general dip of the strata. The upper portion of the seam is bright and black and of medium hardness and appears to be a high grade of

bituminous coal. The lower portion of the seam has more bony streaks but would average a fair grade of bituminous coal.

The following table gives the results of the analyses of some of the coals from the Chignik field. The samples were obtained at the following localities:

6952. Coal bed on west side of main stream, 7 miles northwest of Hook Bay, east side of Chignik Bay, Alaska Peninsula.

6956. Chignik Bay, Thompson Valley, three-fourths of a mile above mouth of stream.

6955. Chignik Lagoon, Whalers Creek, three-fourths of a mile above mouth.

6953. Chignik River, north side, 2 miles below Chignik Lake.

Analyses of Chignik coals.

[Analyses by F. M. Stanton, U. S. Geological Survey.]

Samples as received.

Laboratory No.	Locality.	Proximate analyses.					Ultimate analyses.					Calorific value.	
		Loss on air drying.	Total moisture.	Volatile combustible.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
6952	Near Hook Bay	4.00	5.07	27.24	42.42	25.27	2.26	4.53	55.76	0.59	8.38	5,618	10,112
6956	Thompson Valley	6.50	10.77	30.37	43.99	14.87	.70	4.98	55.27	.61	23.57	5,356	9,641
6955	Whalers Creek	2.50	5.02	34.28	45.45	15.25	1.75	4.87	62.04	.56	15.53	6,245	11,241
6953	Chignik River	5.20	7.06	31.48	39.68	21.78	1.30	4.83	55.14	.61	16.34	5,470	9,846

Air-dried samples (calculated from table above).

Laboratory No.	Locality.	Proximate analyses.			Ultimate analyses.						Calorific value.	
		Moisture.	Volatile combustible.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
6952	Near Hook Bay	1.11	28.38	44.19	26.32	2.35	4.26	58.08	0.61	8.38	5,852	10,533
6956	Thompson Valley	4.57	32.48	47.05	15.90	.75	4.56	59.11	.65	19.03	5,728	10,310
6955	Whalers Creek	2.58	35.16	46.62	15.64	1.79	4.71	63.63	.57	13.66	6,405	11,529
6953	Chignik River	1.96	33.21	41.86	22.97	1.37	4.48	58.17	.64	12.37	5,770	10,386

INDEX.

A.

Page.

Acknowledgments for aid 1–2, 154
Ages of the rocks near the Alaska Railroad 88
Alaska-Juneau mine, operation and production of 24
Alaska Peninsula, animals of 161–162
climate of 158–159
vegetation of 159–161
Alaska Railroad, geography of the region traversed by 80–87
geology of the region traversed by 87–114
map showing geology and mineral deposits of the region traversed by 88
mineral resources of the region traversed by 115–150
Alaska Range, geography of 85
geologic features of 98
glaciers on north slope of 111
igneous rocks of 106
Mesozoic and early Tertiary (?) sediments of 101–102
Paleozoic and older rocks of 98–101
Tertiary coal-bearing formation of 103–104
unconsolidated surface deposits of 104–106
Albert Creek, placer mining on 28
Alder Creek, placer mining on 39
Alfred Creek, placer mining on 28
Allotments for expenses 51–52
Amy Creek, placer mining on 37
Aniak district, in placer mining in 47
Aniakchak Crater, description of 157
pumice and ash ejected from 189
Antimony, occurrence of, near the Alaska Railroad 132–136, 142–143, 147–148
Appropriations, 1898–1922 53
Archangel Creek, mining on 31
Atwood, W. W., cited 194, 211–212

B.

Baker, A. A., Smith, W. R., and, The Cold Bay-Chignik district 151–218
Bear Creek, placer mining on 29
Bear Creek-Salmon Creek anticline, description of 195–196
Becharof Lake syncline, features of 196
Berg Creek, mining operations on 26
Big Creek, mining on 45
Blue Lode group of claims, description of 123–124
Bonnifield region, gold deposits in 138–139
placer mining in 40–41
Broad Pass district, mining in 32
Brooks, Alfred H., Preface 1–2
work of 53–54
and Capps, S. R., The Alaskan mining industry in 1922 3–49
and Martin, George C., Administrative report 51–56
Buckland River basin, discoveries in 48

C.

Page.

Cache Creek, placer mining on 31–32, 129–130
Cahoon Creek, placer development on 25
Candle Creek, dredging on 47
Cantwell formation, bituminous coal in 140–141
nature of 102
Canyon Creek, placer mining on 29
Capps, Stephen R., Geology and mineral resources of the region traversed by the Alaska Railroad 73–150
Brooks, Alfred H., and, The Alaskan mining industry in 1922 3–49
Caribou Creek, hydraulic mining on 42
Chandalar district, mining in 45–46
Chignik Bay region, coal in 211–218
Chignik formation, nature and occurrence of 184–185
Chignik River coal bed, description of 212–213
quality of coal from 216, 218
Chisana district, placer mining in 40
Chisik conglomerate, nature and occurrence of 179–180
Chistochina district, placer mining in 28
Chitina Valley, age of the mineralization in 60–61
copper deposits in 61–68, 71–72
general geology of 57–59
gold deposits in 68–70, 71–72
silver in 70–72
Chititu Creek, placer mining on 27–28
Chugach-Kenai province, location of 89
Chugach Mountains, geography of 80–81
metamorphic and igneous rocks of 89–91
Tertiary deposits of 91
unconsolidated surface deposits of 91
Chulitna, upper, region, geologic sketch map of 132
upper, region, gold and copper lodes in 132–136
region, mining in 32
Circle district, placer mining in 38
Cleary Creek, mining on 35
Coal, condition of mining 18–20
consumption, 1899–1922 19
occurrence of, in the region near the Alaska Railroad 127–128
production, 1888–1922 .... 5, 19, 33, 47
Cold Bay-Chignik district, activities of oil companies in 154
animals of 161–162
climate of 158–159
coal in 211–218
commercial development in 162–163
Cretaceous, Upper, rocks of 184–185
faults in 204–205
field work in 153–154
general geology of 168–171
geologic reconnaissance map of 154
igneous rocks of 189–195
Jurassic rocks of 172–184
location and mapping of 151
petroleum in 205–211

Page.
Cold Bay-Chignik district, population of.. 163–165
previous surveys of.. 151–153
Quaternary deposits of.. 187–189
routes and trails to and in.. 165–168
structure of.. 195–205
Tertiary rocks of.. 185–187
topography of.. 154–157
transportation to and in.. 165–168
Triassic rocks of.. 171–172
vegetation of.. 159–161
Cook Inlet, filling on.. 82
geography of shores of.. 81–83
Cook Inlet-Susitna lowland, glacial deposits in 113
Copper, condition of mining.. 15–16
deposition of, in the Chitina Valley.. 61–68, 72
occurrence of, in the region near the Alaska Railroad.. 118–119, 121–126
production of, 1880, 1900–1922.. 5, 16, 33
Copper Creek, prospecting on.. 27
Copper King group of claims, description of.. 122
Copper Mountain, geology of the ore deposits near.. 42–43
Copper Queen group of claims, description of.. 121–122
Copper River basin, geography of northwest part of.. 84–85
glacial deposits in.. 112–113
mining operations in.. 26–28
Copper River glacier, extent of.. 110
Copper Wonder group of claims, description of.. 122–123
Crazy Mountains, discovery of placer in.. 38
Crooked Creek, placer mining on.. 39
Crow Creek, placer mining on.. 29

D.

Dahl Creek, mining on.. 49
Dan Creek, placer mining on.. 27
Deposits, glacial, in lowlands.. 112–114
Disappointment Creek, mining on.. 45
Discouraging and encouraging factors.. 3–4
Dome Creek, discovery on.. 38
Dredges, operations of.. 14–15
Dry Creek fault, features of.. 195, 196

E.

Eagle district, placer mining in.. 39
Eastview group of claims, description of.. 124
Eldorado Creek, new lodes reported on.. 42
Elephant Mountain anticline, features of.. 204
geologic sketch map of vicinity of.. 190
Elliott Creek, mining operations on.. 26
Encouraging and discouraging factors.. 3–4
Erosion, postglacial, in the region near the Alaska Railroad.. 114
Ester Creek, development on.. 35
Eureka Creek, placer mining on.. 41
Eva Creek, development on.. 40
Expenses that hamper mining.. 115–116

F.

Fairangel Creek, development on.. 31
Fairbanks district, antimony lodes in.. 147–148
glacial deposits in.. 114
gold lodes in.. 146–147
gold placers in.. 144–146
map showing position of lode mines and prospects and placer gravels in.. 144

Page.
Fairbanks district, mining in.. 34–36
tungsten lodes in.. 148
Fairhaven district, mining in.. 47
Farming, condition of.. 75
Fishhook Creek, development on.. 30
Forty-mile district, placer mining in.. 39
Friday Creek, prospecting on.. 42
Fuel on the Alaska Peninsula.. 160–161

G.

Gaines Creek, preparations for dredging on.. 44
Gas, seepage of, in Kejulik Valley.. 206
Geology of the region near the Alaska Railroad, difficulties of surveying.. 87–88
division into geologic provinces.. 89
Georgetown district, mining in.. 47
Glacier Creek, placer mining on.. 41
Glaciers, changes of land forms by.. 112 114
evidence of two advances of.. 111–112
former extent of.. 110–112
former work of.. 82, 84, 87, 91, 97, 105, 187–188
present locations of.. 81, 83, 85–86, 188
process of growth of.. 109–110
Glen Creek, new lodes reported on.. 42
placer mining in basin of.. 41
Glen Gulch, gold quartz discovered on.. 44
Gold, condition of lode mining.. 8–10
condition of placer mining.. 10–15
dredges in operation.. 14
early discoveries.. 6
occurrence of, in the region near the Alaska Railroad.. 117–118, 119–121, 122, 125, 126, 127, 129–131, 132–139, 141–143.
production of, 1880–1922.. 5–8, 10, 12–14, 15, 31, 33–49
Goldstream Creek basin, mining in.. 35
Goodnews Bay, mining near.. 47
Gypsum, condition of mining.. 22

H.

Hammond River, prospecting on.. 46
Hook Bay coal bed, description of.. 215–216
quality of coal from.. 216–217, 218
Hot Springs district, gold deposits in.. 149–150
placer mining in.. 36

I.

Iditarod district, mining in.. 44–45
Information, means of obtaining.. 22–23
Innoko district, mining in.. 43–44
Iron Creek district, copper lodes in.. 121–126
gold lode in.. 121

J.

Juneau district, mining operations in.. 21–25

K.

Kantishna district, antimony lodes in.. 143–144
geologic sketch map of.. 142
geology of the lode deposits in.. 42–43
gold and silver lodes in.. 142–143
gold placers in.. 141–142
placer mining in.. 41–42
Kejulik Mountains, features of.. 192
Kejulik Valley, geologic sketch map of.. 180
structure of.. 199–201
topography of.. 187–188

Page.
Kenai Mountains, geography of 80–81
metamorphic and igneous rocks of 89–91
Tertiary deposits of 91
unconsolidated surface deposits of 91
Kenai Peninsula, copper lodes on 118–119
gold lodes on 117
gold placers on 117–118
mining on 29–30
Kennicott, copper deposits at 62–65, 71
mining operations at 26–27
Ketchikan district, mining operations in 23–24
Kialagvik formation, occurrence and age of 173–176
Klery Creek, mining on 49
Knight Island, development work on 28–29
Kobuk region, mining in 49
Kodiak Island, mining on 33
Koyuk district, mining in 48
Koyukuk district, mining in 46
Kuskokwim region, mining in 47
Kuskulana Valley, copper deposits in 65–67

L.

Lead, condition of mining 16–17
production of, 1892–1922 5, 17, 33, 47
Lignite, occurrence of, in the region near the Alaska Railroad 128, 131–132, 136, 139–141
Little Creek, dredging on 43, 44
Little Eldorado Creek, drift mining on 35
Little Minook Creek, placer mining on 37
Little Squaw Creek, mining on 45
Livengood Creek, placer mining on 37
Lynx Creek, placer mining on 29

M.

McKinley Creek, placer development on 25
McKinley district, mining in 47
Maps issued or prepared 56
Marble, condition of quarrying 22, 23
Marshall district, mining in 45
Martin, George C., Brooks, Alfred H., and, Administrative report 51–56
Mastodon Creek, dredging on 38
Matanuska coal field, description of 127–128
geology of 95
Matanuska region, mining operations in 30–32
Men employed in mining, 1911–1922 5
Metal Creek, placer gold on 32
Mills Creek, placer mining on 29
Mineral Creek, prospecting on 38
Minerals of the region near the Alaska Railroad 115–150
Moffit, Fred H., The metalliferous deposits of Chitina Valley 57–72
Moose Creek, placer mining on 41
Mount Chiginagak, description of 156–157
Mount McKinley, features of 85
Mount McKinley National Park, access to 77–78
Mount Mageik, location of 192
Mount Peulik, description of 189, 191
geologic sketch map of vicinity of 180
structure of area north of 198–199
upturning of strata around 197–198

N.

Naknek formation, nature and occurrence of 178–184

Page.
Nelchina district, dry season in 28
gold placers in 126–127
Nenana coal field, description of 139–141
Nizina district, placer mining in 27
Nolan Creek, mining on 46

O.

Olive Creek, placer mining on 37
Otter Creek, dredging on 44

P.

Pearl Creek dome, drilling on, as a test of the Cold Bay district 211
geologic sketch map of vicinity of 180
location of 197
residue patches on 205–206
Personnel, work of 53–55
Petroleum, drilling for 20–21, 32, 162–163
features that favor accumulation of 206–209
naval reserve withdrawn 21–22
presence of, on Alaska Peninsula 205–211
seepages of other substances resembling 209, 210
Petroleum products, shipments of, to Alaska, 1905–1922 22
Phoenix group of claims, description of 123
Placers, reserves in 11
Platinum metals, occurrence of, in the region near the Alaska Railroad 129, 131
production of, 1916–1922 5, 18, 33, 47
Porcupine Creek, placer development on 25
Port Wells, gold lodes near 117
Prince William Sound, copper lodes on 118–119
mining operations on 28–29
Production, mineral, 1880–1922 5–6
Publications of the year 55–56

Q.

Quicksilver, mining of 47

R.

Railroad, benefits from 73–80
Rainbow Creek, mining on 26
Rampart district, placer mining in 37
Reindeer, raising of 75
Resurrection Creek, placer mining on 29
Rex Creek, placer mining on 27
Richardson district, prospecting in 38
Roads, building of 78
Ruby district, mining in 43

S.

Salmon Creek anticline, description of 195–196
Savage Gulch, prospecting on 38
Scope of the report 1
Seventymile district, placer mining in 39
Seward Peninsula, mining operations on 47–49
Shelikof formation, occurrence and age of 176–178
Shungnak district, mining in 49
Silver, occurrence of, in the region near the Alaska Railroad 119, 120, 122, 125, 142–143, 144
production of 1880–1922 5–8, 10, 12, 31, 33–49
Sitka district, mining operations in 25
Slate Creek, hydraulic mining on 28
Sixtymile River, mining on 46
Smith, Philip S., examination of the Kantishna district by 41

Page.
Smith, W. R., and Baker, A. A., The Cold Bay-Chignik district 151-218
Southeastern Alaska, mining operations in 23-26
Southwestern Alaska, mining in 32-33
Spruce Creek basin, placer mining in 41
Spurr, J. E., cited 200-201
Stanton, T. W., fossils determined by 175-176, 181-183
Stock raising, prospects for 75-76
Stuyahok region, mining in 45
Surveys, progress of, 1898-1922 53
Susitna glacier, extent of 110-111
Susitna lowland, geography of 81-83
Susitna-Matanuska region, mining operations in 30-32
Susitna River basin, geography of upper part of 84-85

T.

Talkeetna district, mining in 32
Talkeetna group of claims, description of 124-125
Talkeetna Mountains, area of the geologic province 89, 91
copper lodes in 121-126
geography of 83-84
geology of 91-98
gold lodes in 119-121
gold placers near 119
Mesozoic igneous rocks of 93-94
Mesozoic sediments of 92-93
paleozoic or older rocks of 92
Tertiary igneous rocks of 96
Tertiary sediments of 94-96
unconsolidated surface deposits of 96-98
western, geologic sketch map of 120
Tanana lowland, geography of 86
glacial deposits in 113-114
Tanana upland. *See* Yukon-Tanana upland.
Thompsons Valley coal beds, description of 214-215
quality of coal from 216, 218
Tin, condition of mining 17
occurrence of, in the region near the Alaska Railroad 129, 131, 149
production of, 1902-1922 5, 17, 33
Tolovana district, placer mining in 37
Tolstoi district, mining in 44
Topography of central Alaska in early Quaternary time 108-109

Page.
Totatlanika schist, nature of 98-99, 100
Tourists, transportation for 78-80
Tuluksak district, mining in 47
Tungsten, occurrence of, in the region near the Alaska Railroad 129, 148
Turnagain Arm, gold placers near 118

U.

Ugashik Creek anticline, description of 197, 202-204
Unga Island, mining on 33

V.

Valdez, mining operations near 28, 29
Valdez Creek district, gold placers in 136-137
mining in 32
Volcanoes, active, on Alaska Peninsula 192
extinct, on Alaska Peninsula 191-192

W.

Wade Creek, placer mining on 39
Whalers Creek coal bed, description of 213-214
quality of coal from 216, 218
Wide Bay, geologic sketch map of vicinity of 190
Wide Bay anticline, description of 201-202
Wilbur Creek, poor pay streak on 37
Willow Creek district, gold lodes of 120-121
mining operations in 30-31
sketch map showing location of mines and prospects in 120
Work of the personnel 53-55
Wrangell district, mining operations in 24

Y.

Yakataga, placer mining at 26
Yankee Creek, dredging on 43, 44
Yentna district, geologic sketch map of 128
gold placers in 128-132
mining in 31-32
Young Creek, placer mining on 27, 28
Yukon Basin, mining operations in 33-46
Yukon-Tanana upland, features of 106-107
geography of 86-87
igneous rocks of 108
Mesozoic and Tertiary sediments of 108
Paleozoic or older metamorphic rocks of 107
Paleozoic sediments of 107-108
unconsolidated surface deposits of 108

RECENT SURVEY PUBLICATIONS ON ALASKA.

[Arranged geographically. A complete list can be had on application.]

All these publications can be obtained or consulted in the following ways:

1. A certain number of copies are delivered to the Director of the Survey, from whom they can be obtained for a limited period free of charge (except certain maps) on application.

2. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at the prices indicated. No copies are available of those marked with an asterisk (*); they may be consulted at many public libraries.

3. Copies of all Government publications are furnished to the principal public libraries throughout the United States, where they can be consulted by those interested.

The maps whose price is stated are sold by the Geological Survey and not by the Superintendent of Documents. On an order for maps amounting to $5 or more at the retail price a discount of 40 per cent is allowed.

GENERAL.

REPORTS.

*The geography and geology of Alaska, a summary of existing knowledge, by A. H. Brooks, with a section on climate, by Cleveland Abbe, jr., and a topographic map and description thereof, by R. U. Goode. Professional Paper 45, 1906, 327 pp.

Placer mining in Alaska in 1904, by A. H. Brooks. In Bulletin 259, 1905, pp. 18-31. 15 cents.

The mining industry in 1905, by A. H. Brooks. In Bulletin 284, 1906, pp. 4-9. 25 cents.

The mining industry in 1906, by A. H. Brooks. In Bulletin 314, 1907, pp. 19-39. 30 cents.

The mining industry in 1907, by A. H. Brooks. In Bulletin 345, 1908, pp. 30-53. 45 cents.

The mining industry in 1908, by A. H. Brooks. In Bulletin 379, 1909, pp. 21-62. 50 cents.

The mining industry in 1909, by A. H. Brooks. In Bulletin 442, 1910, pp. 20-46. 40 cents.

Alaska coal and its utilization. Bulletin 442-J, reprinted 1914. 10 cents.

The mining industry in 1910, by A. H. Brooks. In Bulletin 480, 1911, pp. 21-42. 40 cents.

The mining industry in 1911, by A. H. Brooks. In Bulletin 520, 1912, pp. 19-44. 50 cents.

The mining industry in 1912, by A. H. Brooks. In Bulletin 542, 1913, pp. 18-51. 25 cents.

The Alaskan mining industry in 1913, by A. H. Brooks. In Bulletin 592, 1914, pp. 45-74. 60 cents.

The Alaskan mining industry in 1914, by A. H. Brooks. In Bulletin 622, 1915, pp. 15-68. 30 cents.

The Alaskan mining industry in 1915, by A. H. Brooks. In Bulletin 642, 1916, pp. 17-72. 35 cents.

The Alaskan mining industry in 1916, by A. H. Brooks. In Bulletin 662, 1917, pp. 11–62. 75 cents.

*The Alaskan mining industry in 1917, by G. C. Martin. In Bulletin 692, 1918, pp. 11–42.

*The Alaskan mining industry in 1918, by G. C. Martin. In Bulletin 712, 1919, pp. 11–52.

The Alaskan mining industry in 1919, by A. H. Brooks and G. C. Martin. Bulletin 714–A, reprinted 1921. 25 cents.

The Alaskan mining industry in 1920, by A. H. Brooks. In Bulletin 722, 1921, pp. 7–67. 25 cents.

The Alaskan mining industry in 1921, by A. H. Brooks. Bulletin 739–A, 1922, pp. 1–44. 10 cents.

The Alaskan mining industry in 1922, by A. H. Brooks and S. R. Capps. In Bulletin 755, 1924, pp. 3–49. Free on application.

Alaska's minerals and production, 1923, by Alfred H. Brooks. In Bulletin 773, 1925, pp. ———. Free on application.

Railway routes, by A. H. Brooks. In Bulletin 284, 1906, pp. 10–17. 25 cents.

Railway routes from the Pacific seaboard to Fairbanks, Alaska, by A. H. Brooks. In Bulletin 520, 1912, pp. 45–88. 50 cents.

Geologic features of Alaskan metalliferous lodes, by A. H. Brooks. In Bulletin 480, 1911, pp. 43–93. 40 cents.

The mineral deposits of Alaska, by A. H. Brooks. In Bulletin 592, 1914, pp. 18–44. 60 cents.

The future of gold-placer mining in Alaska, by A. H. Brooks. In Bulletin 622, 1915, pp. 69–79. 30 cents.

Tin resources of Alaska, by F. L. Hess. In Bulletin 520, 1912, pp. 89–92. 50 cents.

Alaska coal and its utilization, by A. H. Brooks. Bulletin 442–J, reprinted 1914 10 cents.

The possible use of peat fuel in Alaska, by C. A. Davis. In Bulletin 379, 1909, pp. 63–66. 50 cents.

The preparation and use of peat as a fuel, by C. A. Davis. In Bulletin 442, 1910, pp. 101–132. 40 cents.

*Methods and costs of gravel and placer mining in Alaska, by C. W. Purington. Bulletin 263, 1905, 362 pp. (Abstract in Bulletin 259, 1905, pp. 32–46, 15 cents.)

Prospecting and mining gold placers in Alaska, by J. P. Hutchins. In Bulletin 345, 1908, pp. 54–77. 45 cents.

*Geographic dictionary of Alaska, by Marcus Baker; second edition prepared by James McCormick. Bulletin 299, 1906, 690 pp.

Tin mining in Alaska, by H. M. Eakin. In Bulletin 622, 1915, pp. 81–94. 30 cents.

Antimony deposits of Alaska, by A. H. Brooks. Bulletin 649, 1916, 67 pp. 15 cents.

*The use of the panoramic camera in topographic surveying, by J. W. Bagley. Bulletin 657, 1917, 88 pp.

The mineral springs of Alaska, by G. A. Waring. Water-Supply Paper 418, 1917, 114 pp. 25 cents.

Alaska's mineral supplies, by A. H. Brooks. Bulletin 666–P, 14 pp. 5 cents.

The future of Alaska mining, by A. H. Brooks. Bulletin 714–A, reprinted 1921. 25 cents.

Preliminary report on petroleum in Alaska, by G. C. Martin. Bulletin 719, 1921, 83 pp. 50 cents.

In preparation.

The Mesozoic stratigraphy of Alaska, by George C. Martin.

The Upper Cretaceous flora of Alaska, by Arthur Hollick, with a description of the Upper Cretaceous plant-bearing beds, by George C. Martin.

TOPOGRAPHIC MAPS.

Map of Alaska (A); scale, 1:5,000,000; 1920, by A. H. Brooks. 10 cents retail or 6 cents wholesale.
*Map of Alaska (B); scale, 1:1,500,000; 1915, by A. H. Brooks and R. H. Sargent.
Map of Alaska (C); scale, 1:12,000,000; 1916. 1 cent retail or five for 3 cents wholesale.
Map of Alaska showing distribution of mineral deposits; scale, 1:5,000,000; by A. H. Brooks. 20 cents retail or 12 cents wholesale. New editions included in Bulletins 642 (35 cents), 662 (75 cents), and 714–A (25 cents).
Index map of Alaska, including list of publications; scale, 1:5,000,000; by A. H. Brooks. Free on application.
Relief map of Alaska (D); scale, 1:2,500,000; 1923, by A. H. Brooks and R. H. Sargent. 50 cents retail or 30 cents wholesale.
Map of Alaska (E); scale, 1:2,500,000; 1923, by A. H. Brooks and R. H. Sargent. 25 cents retail or 15 cents wholesale.

SOUTHEASTERN ALASKA.

REPORTS.

Economic developments in southeastern Alaska, by F. E. and C. W. Wright. In Bulletin 259, 1905, pp. 47–68. 15 cents.
The Juneau gold belt, Alaska, by A. C. Spencer, pp. 1–137, and A reconnaissance of Admiralty Island, Alaska, by C. W. Wright, pp. 138–154. Bulletin 287, 1906, 161 pp. 75 cents.
Lode mining in southeastern Alaska, by F. E. and C. W. Wright. In Bulletin 284, 1906, pp. 30–53. 25 cents.
Nonmetallic deposits of southeastern Alaska, by C. W. Wright. In Bulletin 284, 1906, pp. 54–60. 25 cents.
Lode mining in southeastern Alaska, by C. W. Wright. In Bulletin 314, 1907, pp. 47–72. 30 cents.
Nonmetalliferous mineral resources of southeastern Alaska, by C. W. Wright. In Bulletin 314, 1917, pp. 73–81. 30 cents.
Reconnaissance on the Pacific coast from Yakutat to Alsek River, by Eliot Blackwelder. In Bulletin 314, 1907, pp. 82–88. 30 cents.
Lode mining in southeastern Alaska, 1907, by C. W. Wright. In Bulletin 345, 1908, pp. 78–97. 45 cents.
The building stones and materials of southeastern Alaska, by C. W. Wright. In Bulletin 345, 1908, pp. 116–126. 45 cents.
The Ketchikan and Wrangell mining districts, Alaska, by F. E. and C. W. Wright. Bulletin 347, 1908, 210 pp. 60 cents.
The Yakutat Bay region, Alaska: Physiography and glacial geology, by R. S. Tarr; Areal geology, by R. S. Tarr and B. S. Butler. Professional Paper 64, 1909, 186 pp. 50 cents.
Mining in southeastern Alaska, by C. W. Wright. In Bulletin 379, 1909, pp. 67–86. 50 cents.
Mining in southeastern Alaska, by Adolph Knopf. In Bulletin 442, 1910, pp. 133–143. 40 cents.
Occurrence of iron ore near Haines, by Adolph Knopf. In Bulletin 442, 1910, pp. 144–146. 40 cents.
Report of water-power reconnaissance in southeastern Alaska, by J. C. Hoyt. In Bulletin 442, 1910, pp. 147–157. 40 cents.
Geology of the Berners Bay region, Alaska, by Adolph Knopf. Bulletin 446, 1911, 58 pp. 20 cents.
Mining in southeastern Alaska, by Adolph Knopf. In Bulletin 480, 1911, pp. 94–102. 40 cents.

The Eagle River region, southeastern Alaska, by Adolph Knopf. Bulletin 502, 1912, 61 pp. 25 cents.

The Sitka mining district, Alaska, by Adolph Knopf. Bulletin 504, 1912, 32 pp. 5 cents.

The earthquakes at Yakutat Bay, Alaska, in September, 1899, by R. S. Tarr and Lawrence Martin, with a preface by G. K. Gilbert. Professional Paper 69, 1912, 135 pp. 60 cents.

A barite deposit near Wrangell, by E. F. Burchard. In Bulletin 592, 1914, pp. 109–117. 60 cents.

Lode mining in the Ketchikan district, by P. S. Smith. In Bulletin 592, 1914, pp. 75–94. 60 cents.

The geology and ore deposits of Copper Mountain and Kasaan Peninsula, Alaska, by C. W. Wright. Professional Paper 87, 1915, 110 pp. 40 cents.

Mining in the Juneau region, by H. M. Eakin. In Bulletin 622, 1915, pp. 95–102. 30 cents.

Notes on the geology of Gravina Island, Alaska, by P. S. Smith. Professional Paper 95–H, 1916, 9 pp. 30 cents.

Mining in southeastern Alaska, by Theodore Chapin. In Bulletin 642, 1916, pp. 73–104. 35 cents.

Water-power investigations in southeastern Alaska, by G. H. Canfield. In Bulletin 642, 1916, pp. 105–127. 35 cents.

Mining developments in the Ketchikan and Wrangell districts, by Theodore Chapin. In Bulletin 662, 1917, pp. 63–75. 75 cents.

Lode mining in the Juneau gold belt, by H. M. Eakin. In Bulletin 662, 1917, pp. 71–92. 75 cents.

Gold-placer mining in the Porcupine district, by H. M. Eakin. In Bulletin 662, 1917, pp. 93–100. 75 cents.

Water-power investigations in southeastern Alaska, by G. H. Canfield. In Bulletin 662, 1917, pp. 101–154. 75 cents.

*Water-power investigations in southeastern Alaska, by G. H. Canfield. In Bulletin 692, 1919, pp. 43–83.

*The structure and stratigraphy of Gravina and Revillagigedo islands, Alaska, by Theodore Chapin. Professional Paper 120–D, 1918, 18 pp.

*Mining developments in the Ketchikan mining district, by Theodore Chapin. In Bulletin 692, 1919, pp. 85–89.

*The geology and mineral resources of the west coast of Chichagof Island, by R. M. Overbeck. In Bulletin 692, 1919, pp. 91–136.

The Porcupine district, by H. M. Eakin. Bulletin 699, 1919, 29 pp. 20 cents.

*Water-power investigations in southeastern Alaska, by G. H. Canfield. In Bulletin 712, 1920, pp. 53–90.

*Lode mining in the Juneau and Ketchikan districts, by J. B. Mertie, jr. In Bulletin 714, 1921, pp. 105–128.

*Notes on the Unuk-Salmon River region, by J. B. Mertie, jr. In Bulletin 714, 1921, pp. 129–142.

*Water-power investigations in southeastern Alaska, by G. H. Canfield. In Bulletin 714, 1921, pp. 143–187.

Marble deposits of southeastern Alaska, by E. F. Burchard. Bulletin 682, 1920, 118 pp. 30 cents.

Water-power investigations in southeastern Alaska, by G. H. Canfield. In Bulletin 722, 1922, pp. 75–115. 25 cents.

Ore deposits of the Salmon River district, Portland Canal region, Alaska, by L. G. Westgate. In Bulletin 722, 1922, pp. 117–140. 25 cents.

Mineral deposits of the Wrangell district, by A. F. Buddington. In Bulletin 739, 1923, pp. 51–75. 25 cents.

Mineral resources of southeastern Alaska, by A. F. Buddington. In Bulletin 773, 1925, pp. ———. Free on application.

In preparation.

Geology and ore deposits of the Juneau district, by H. M. Eakin.
The Ketchikan district, by Theodore Chapin.

TOPOGRAPHIC MAPS.

Juneau gold belt, Alaska; scale, 1:250,000; compiled. In Bulletin 287, 75 cents. Not issued separately.
Juneau special (No. 581A); scale, 1:62,500; by W. J. Peters. 10 cents retail or 6 cents wholesale.
Berners Bay special (No. 581B); scale, 1:62,500; by R. B. Oliver. 10 cents retail or 6 cents wholesale. Also contained in Bulletin 446, 20 cents.
Kasaan Peninsula, Prince of Wales Island (No. 540A); scale, 1:62,500; by D. C. Witherspoon, R. H. Sargent, and J. W. Bagley. 10 cents retail or 6 cents wholesale. Also contained in Professional Paper 87, 40 cents.
Copper Mountain and vicinity, Prince of Wales Island (No. 540B); scale, 1:62,500; by R. H. Sargent. 10 cents retail or 6 cents wholesale. Also contained in Professional Paper 87, 40 cents.
Eagle River region (No. 581C); scale, 1:62,500; by J. W. Bagley, C. E. Giffin, and R. E. Johnson. In Bulletin 502, 25 cents. Not issued separately.
Juneau and vicinity (No. 581D); scale, 1:24,000; contour interval, 50 feet; by D. C. Witherspoon. 20 cents.

CONTROLLER BAY, PRINCE WILLIAM SOUND, AND COPPER RIVER REGIONS.

REPORTS.

Geology of the central Copper River region, Alaska, by W. C. Mendenhall. Professional Paper 41, 1905, 133 pp. 50 cents.
Geology and mineral resources of Controller Bay region, Alaska, by G. C. Martin. Bulletin 335, 1908, 141 pp. 70 cents.
Notes on copper prospects of Prince William Sound, by F. H. Moffit. In Bulletin 345, 1908, pp. 176–178. 45 cents.
Mineral resources of the Kotsina-Chitina region, by F. H. Moffit and A. G. Maddren. Bulletin 374, 1909, 103 pp. 40 cents.
Copper mining and prospecting on Prince William Sound, by U. S. Grant and D. F. Higgins, jr. In Bulletin 379, 1909, pp. 78–96. 50 cents.
Mining in the Kotsina-Chitina, Chistochina, and Valdez Creek regions, by F. H. Moffit. In Bulletin 379, 1909, pp. 153–160. 50 cents.
Mineral resources of the Nabesna-White River district, by F. H. Moffit and Adolph Knopf; with a section on the Quaternary, by S. R. Capps. Bulletin 417, 1910, 64 pp. 25 cents.
Mining in the Chitina district, by F. H. Moffit. In Bulletin 442, 1910, pp. 158–163. 40 cents.
Mining and prospecting on Prince William Sound in 1909, by U. S. Grant. In Bulletin 442, 1910, pp. 164–165. 40 cents.
Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska, by U. S. Grant and D. F. Higgins. Bulletin 443, 1910, 89 pp. 45 cents.
Geology and mineral resources of the Nizina district, Alaska, by F. H. Moffit and S. R. Capps. Bulletin 448, 1911, 111 pp. 40 cents.
Headwater regions of Gulkana and Susitna rivers, Alaska, with accounts of the Valdez Creek and Chistochina placer districts, by F. H. Moffit. Bulletin 498, 1912, 82 pp. 35 cents.
The Chitina district, by F. H. Moffit. In Bulletin 520, 1912, pp. 105–107. 50 cents.

Coastal glaciers of Prince William Sound and Kenai Peninsula, Alaska, by U. S. Grant and D. F. Higgins. Bulletin 526, 1913, 75 pp. 30 cents.

The McKinley Lake district, by Theodore Chapin. In Bulletin 542, 1913, pp. 78–80. 25 cents.

Mining in Chitina Valley, by F. H. Moffit. In Bulletin 542, 1913, pp. 81–85. 25 cents.

Mineral deposits of the Ellamar district, by S. R. Capps and B. L. Johnson. In Bulletin 542, 1913, pp. 86–124. 25 cents.

The mineral deposits of the Yakataga region, by A. G. Maddren. In Bulletin 592, 1914, pp. 119–154. 60 cents.

The Port Wells gold-lode district, by B. L. Johnson. In Bulletin 592, 1914, pp. 195–236. 60 cents.

Mining on Prince William Sound, by B. L. Johnson. In Bulletin 592, 1914, pp. 237–244. 60 cents.

The geology and mineral resources of Kenai Peninsula, by G. C. Martin, B. L. Johnson, and U. S. Grant. Bulletin 587, 1915, 243 pp. 70 cents.

Mineral deposits of the Kotsina-Kuskulana district, with notes on mining in Chitina Valley, by F. H. Moffit. In Bulletin 622, 1915, pp. 103–117. 30 cents.

Mining on Prince William Sound, by B. L. Johnson. In Bulletin 622, 1915, pp. 131–139. 30 cents.

The gold and copper deposits of the Port Valdez district, by B. L. Johnson. In Bulletin 622, 1915, pp. 140–188. 30 cents.

The Ellamar district, by S. R. Capps and B. L. Johnson. Bulletin 605, 1915, 125 pp. 25 cents.

*A water-power reconnaissance in south-central Alaska, by C. E. Ellsworth and R. W. Davenport. Water-Supply Paper 372, 173 pp.

Mining on Prince William Sound, by B. L. Johnson. In Bulletin 642, 1916, pp. 137–145. 35 cents.

Mining in the lower Copper River basin, by F. H. Moffit. In Bulletin 662, 1917, pp. 155–182. 75 cents.

*Retreat of Barry Glacier, Port Wells, Prince William Sound, Alaska, between 1910 and 1914, by B. L. Johnson. In Professional Paper 98, 1916, pp. 35–36.

Mining on Prince William Sound, by B. L. Johnson. In Bulletin 662, 1917, pp. 183–192. 75 cents.

Copper deposits of the Latouche and Knight Island districts, Prince William Sound, by B. L. Johnson. In Bulletin 662, 1917, pp. 193–220. 75 cents.

The Nelchina-Susitna region, by Theodore Chapin. Bulletin 668, 1918, 67 pp. 25 cents.

The upper Chitina Valley, by F. H. Moffit, with a description of the igneous rocks, by R. M. Overbeck. Bulletin 675, 1918, 82 pp. 25 cents.

*Platinum-bearing auriferous gravels of Chistochina River, by Theodore Chapin. In Bulletin 692, 1919, pp. 137–141.

*Mining on Prince William Sound, by B. L. Johnson. In Bulletin 692, 1919, pp. 143–151.

*The Jack Bay district and vicinity, by B. L. Johnson. In Bulletin 692, 1919, pp. 153–173.

*Mining in central and northern Kenai Peninsula in 1917, by B. L. Johnson. In Bulletin 692, 1919, pp. 175–176.

*Nickel deposits in the lower Copper River valley, by R. M. Overbeck. In Bulletin 712, 1919, pp. 91–98.

*Mining in Chitina Valley, by F. H. Moffit. In Bulletin 714, 1921, pp. 189–196.

The Kotsina-Kuskulana district, Alaska, by F. H. Moffit. Bulletin 745, 1923, 149 pp. 40 cents.

The metalliferous deposits of Chitina Valley, by Fred H. Moffit. In Bulletin 755, 1924, pp. 57–72. Free on application.

The occurrence of copper on Prince William Sound, by Fred H. Moffit. In Bulletin 773, 1925, pp. ———. Free on application.

In preparation.

Geology of the Chitina quadrangle, by Fred H. Moffit

TOPOGRAPHIC MAPS.

Central Copper River region; scale, 1:250,000; by T. G. Gerdine. In Professional Paper 41, 50 cents. Not issued separately.

Headwater regions of Copper, Nabesna, and Chisana rivers; scale, 1:250,000; by D. C. Witherspoon, T. G. Gerdine, and W. J. Peters. In Professional Paper 41, 50 cents. Not issued separately.

Controller Bay region (No. 601A); scale, 1:62,500; by E. G. Hamilton and W. R. Hill. 35 cents retail or 21 cents wholesale. Also published in Bulletin 335, 70 cents.

Chitina quadrangle (No. 601); scale, 1:250,000; by T. G. Gerdine, D. C. Witherspoon, and others. 50 cents retail or 30 cents wholesale. Also published in Bulletin 576, 30 cents.

Nizina district (No. 601B); scale, 1:62,500; by D. C. Witherspoon and R. M. La Follette. In Bulletin 448, 40 cents. Not issued separately.

Headwater regions of Gulkana and Susitna rivers; scale, 1:250,000; by D. C. Witherspoon, J. W. Bagley, and C. E. Giffin. In Bulletin 498, 35 cents. Not issued separately.

Prince William Sound; scale, 1:500,000; compiled. In Bulletin 526, 30 cents. Not issued separately.

Port Valdez district (No. 602B); scale, 1:62,500; by J. W. Bagley. 20 cents retail or 12 cents wholesale.

The Bering River coal fields; scale, 1:62,500; by G. C. Martin. 25 cents retail or 15 cents wholesale.

The Ellamar district (No. 602D); scale, 1:62,500; by R. H. Sargent and C. E. Giffin. Published in Bulletin 605, 25 cents. Not issued separately.

Nelchina-Susitna region; scale, 1:250,000; by J. W. Bagley, T. G. Gerdine, and others. In Bulletin 668, 25 cents. Not issued separately.

Upper Chitina Valley; scale, 1:250,000; by International Boundary Commission, F. H. Moffit, D. C. Witherspoon, and T. G. Gerdine. In Bulletin 675, 25 cents. Not issued separately.

The Kotsina-Kuskulana district (No. 601C); scale, 1:62,500; by D. C. Witherspoon. 10 cents. Also published in Bulletin 745, 40 cents.

In preparation.

Prince William Sound region; scale, 1:180,000; by J. W. Bagley.

COOK INLET AND SUSITNA REGION.

REPORTS.

Gold placers of the Mulchatna, by F. J. Katz. In Bulletin 442, 1910, pp. 201–202. 40 cents.

Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska, by Sidney Paige and Adolph Knopf. Bulletin 327, 1907, 71 pp. 25 cents.

*The Mount McKinley region, Alaska, by A. H. Brooks, with description of the igneous rocks and of the Bonnifield and Kantishna districts, by L. M. Prindle. Professional Paper 70, 1911, 234 pp.

A geologic reconnaissance of the Iliamna region, Alaska, by G. C. Martin and F. J. Katz. Bulletin 485, 1912, 138 pp. 35 cents.

Geology and coal fields of the lower Matanuska Valley, Alaska, by G. C. Martin and F. J. Katz. Bulletin 500, 1912, 98 pp. 30 cents.

The Yentna district, Alaska, by S. R. Capps. Bulletin 534, 1913, 75 pp. 20 cents.

Mineral resources of the upper Matanuska and Nelchina valleys, by G. C. Martin and J. B. Mertie, jr. In Bulletin 592, 1914, pp. 273–300. 60 cents.

Mining in the Valdez Creek placer district, by F. H. Moffit. In Bulletin 592, 1914, pp. 307–308. 60 cents.

The geology and mineral resources of Kenai Peninsula, Alaska, by G. C. Martin, B. L. Johnson, and U. S. Grant. Bulletin 587, 1915, 243 pp. 70 cents.

The Willow Creek district, by S. R. Capps. Bulletin 607, 1915, 86 pp. 25 cents.

The Broad Pass region, by F. H. Moffit and J. E. Pogue. Bulletin 608, 1915, 80 pp. 25 cents.

The Turnagain-Knik region, by S. R. Capps. In Bulletin 642, 1916, pp. 147–194. 35 cents.

Gold mining in the Willow Creek district, by S. R. Capps. In Bulletin 642, 1916, pp. 195–200. 35 cents.

The Nelchina-Susitna region, by Theodore Chapin. Bulletin 668, 1918, 67 pp. 25 cents.

*Mineral resources of the upper Chulitna region, by S. R. Capps. In Bulletin 692, 1919, pp. 207–232.

*Gold-lode mining in the Willow Creek district, by S. R. Capps. In Bulletin 692, 1919, pp. 177–186.

*Mineral resources of the western Talkeetna Mountains, by S. R. Capps. In Bulletin 692, 1919, pp. 187–205.

*Platinum-bearing gold placers of Kahiltna Valley, by J. B. Mertie, jr. In Bulletin 692, 1919, pp. 233–264.

*Chromite deposits of Alaska, by J. B. Mertie, jr. In Bulletin 692, 1919, pp. 265–267.

*Geologic problems at the Matanuska coal mines, by G. C. Martin. In Bulletin 692, 1919, pp. 269–282.

*Preliminary report on chromite of Kenai Peninsula, by A. C. Gill. In Bulletin 712, 1920, pp. 99–129.

*Mining in the Matanuska coal field and the Willow Creek district, by Theodore Chapin. In Bulletin 712, 1920, pp. 131–176.

*Mining developments in the Matanuska coal fields, by Theodore Chapin. In Bulletin 714, 1921, pp. 197–199.

*Lode developments in the Willow Creek district, by Theodore Chapin. In Bulletin 714, 1921, pp. 201–206.

Geology in the vicinity of Tuxedni Bay, Cook Inlet, by F. H. Moffit. In Bulletin 722, 1922, pp. 141–147. 25 cents.

The Iniskin Bay district, by F. H. Moffit. In Bulletin 739, 1922, pp. 117–132. 25 cents.

Petroleum seepage near Anchorage, by A. H. Brooks. In Bulletin 739, 1922, pp. 133–147. 25 cents.

Chromite of Kenai Peninsula, Alaska, by A. C. Gill. Bulletin 742, 1922, 52 pp. 15 cents.

Geology and mineral resources of the region traversed by the Alaska Railroad, by S. R. Capps. In Bulletin 755, 1924, pp. 73–150. Free on application.

An early Tertiary deposit in the Yentna district, by S. R. Capps. In Bulletin 773, 1925, pp. ———. Free on application.

Mineral resources of the Kamishak Bay region, by K. F. Mather. In Bulletin 773, 1925, pp. ———. Free on application.

Aniakchak Crater, Alaska Peninsula, by W. R. Smith. In Professional Paper 132, 1925, pp. ———. Free on application.

In preparation.

The Alaska Railroad route, by S. R. Capps.
Geology of the Iniskin-Chinitna Peninsula, by F. H. Moffit.

TOPOGRAPHIC MAPS.

Kenai Peninsula, southern portion; scale, 1:500,000; compiled. In Bulletin 526, 30 cents. Not issued separately.
Matanuska and Talkeetna region; scale, 1:250,000; by T. G. Gerdine and R. H. Sargent. In Bulletin 327, 25 cents. Not issued separately.
Lower Matanuska Valley; scale, 1:62,500; by R. H. Sargent. In Bulletin 500, 30 cents. Not issued separately.
Yentna district; scale, 1:250,000; by R. W. Porter. Revised edition. In Bulletin 534, 20 cents. Not issued separately.
*Mount McKinley region; scale, 1:625,000; by D. L. Reaburn. In Professional Paper 70. Not issued separately.
Kenai Peninsula; scale, 1:250,000; by R. H. Sargent, J. W. Bagley, and others. In Bulletin 587, 70 cents. Not issued separately.
Moose Pass and vicinity (No. 602C); scale, 1:62,500; by J. W. Bagley. In Bulletin 587, 70 cents. Not issued separately.
The Willow Creek district; scale, 1:62,500; by C. E. Giffin. In Bulletin 607, 25 cents. Not issued separately.
The Broad Pass region; scale, 1:250,000; by J. W. Bagley. In Bulletin 608, 25 cents. Not issued separately.
Lower Matanuska Valley (No. 602A); scale, 1:62,500; by R. H. Sargent. 10 cents.
Nelchina-Susitna region; scale, 1:250,000; by J. W. Bagley. In Bulletin 668, 25 cents. Not issued separately.
Iniskin-Chinitna Peninsula, Cook Inlet region; scale, 1:62,500; by C. P. McKinley, D. C. Witherspoon, and Gerald Fitz Gerald (preliminary edition). Free on application.
The Alaska Railroad route: Seward to Matanuska coal field; scale, 1:250,000; by J. W. Bagley, T. G. Gerdine, R. H. Sargent, and others. 50 cents retail or 30 cents wholesale.
The Alaska Railroad route: Matanuska coal field to Yanert Fork; scale, 1:250,000; by J. W. Bagley, T. G. Gerdine, R. H. Sargent, and others. 50 cents retail or 30 cents wholesale.
The Alaska Railroad route: Yanert Fork to Fairbanks; scale, 1:250,000; by J. W. Bagley, T. G. Gerdine, R. H. Sargent, and others. 50 cents retail or 30 cents wholesale.
Iniskin Bay-Snug Harbor district, Cook Inlet region, Alaska; scale, 1:250,000; by C. P. McKinley and Gerald Fitz Gerald (preliminary edition). Free on application.

SOUTHWESTERN ALASKA.

REPORTS.

A reconnaissance in southwestern Alaska, by J. E. Spurr. In Twentieth Annual Report, pt. 7, 1900, pp. 31–264. $1.80.
Gold mines on Unalaska Island, by A. J. Collier. In Bulletin 259, 1905, pp. 102–103. 15 cents.
*Geology and mineral resources of parts of Alaska Peninsula, by W. W. Atwood. Bulletin 467, 1911, 137 pp.
A geologic reconnaissance of the Iliamna region, Alaska, by G. C. Martin and F. J. Katz. Bulletin 485, 1912, 138 pp. 35 cents.

Mineral deposits of Kodiak and the neighboring islands, by G. C. Martin. In Bulletin 542, 1913, pp. 125–136. 25 cents.

The Lake Clark-central Kuskokwim region, by P. S. Smith. Bulletin 655, 1918, 162 pp. 30 cents.

*Beach placers of Kodiak Island, Alaska, by A. G. Maddren. In Bulletin 692, 1919, pp. 299–319.

*Sulphur on Unalaska and Akun islands and near Stepovak Bay, Alaska, by A. G. Maddren. In Bulletin 692, 1919, pp. 283–298.

The Cold Bay district, by S. R. Capps. In Bulletin 739, 1922, pp. 77–116. 25 cents.

The Cold Bay-Chignik district, by W. R. Smith and A. A. Baker. In Bulletin 755, 1924, pp. 151–218. Free on application.

The Cold Bay-Katmai district, by Walter R. Smith. In Bulletin 773, 1925, pp. ———. Free on application.

The outlook for petroleum near Chignik, by G. C. Martin. In Bulletin 773, 1925, pp. ———. Free on application.

TOPOGRAPHIC MAPS.

*Herendeen Bay and Unga Island region; scale 1:250,000; by H. M. Eakin. In Bulletin 467. Not issued separately.

*Chignik Bay region; scale, 1:250,000; by H. M. Eakin. In Bulletin 467. Not issued separately.

Iliamna region; scale, 1:250,000; by D. C. Witherspoon and C. E. Giffin. In Bulletin 485, 35 cents. Not issued separately.

Kuskokwim River and Bristol Bay region; scale, 1:625,000; by W. S. Post. In Twentieth Annual Report, pt. 7, $1.80. Not issued separately.

Lake Clark-central Kuskokwim region; scale, 1:250,000; by R. H. Sargent, D. C. Witherspoon, and C. E. Giffin. In Bulletin 655, 30 cents. Not issued separately.

Cold Bay-Chignik region, Alaska Peninsula; scale, 1:250,000; by R. K. Lynt and R. H. Sargent (preliminary edition). Free on application.

YUKON AND KUSKOKWIM BASINS.

REPORTS.

The coal resources of the Yukon, Alaska, by A. J. Collier. Bulletin 218, 1903, 71 pp. 15 cents.

The Fortymile quadrangle, Yukon-Tanana region, Alaska, by L. M. Prindle. Bulletin 375, 1909, 52 pp. 30 cents.

Water-supply investigations in Yukon-Tanana region, Alaska, 1907–8 (Fairbanks, Circle, and Rampart districts), by C. C. Covert and C. E. Ellsworth. Water-Supply Paper 228, 1909, 108 pp. 20 cents.

The Innoko gold-placer district, Alaska, with accounts of the central Kuskokwim Valley and the Ruby Creek and Gold Hill placers, by A. G. Maddren. Bulletin 410, 1910, 87 pp. 40 cents.

Mineral resources of the Nabesna-White River district, Alaska, by F. H. Moffit and Adolph Knopf, with a section on the Quaternary by S. R. Capps. Bulletin 417, 1910, 64 pp. 25 cents.

Placer mining in the Yukon-Tanana region, by C. E. Ellsworth. In Bulletin 442, 1910, pp. 230–245. 40 cents.

Occurrence of wolframite and cassiterite in the gold placers of Deadwood Creek, Birch Creek district, by B. L. Johnson. In Bulletin 442, 1910, pp. 246–250. 40 cents.

Placer mining in the Yukon-Tanana region, by C. E. Ellsworth and G. L. Parker. In Bulletin 480, 1911, pp. 153–172. 40 cents.

Gold-placer mining developments in the Innoko-Iditarod region, by A. G. Maddren. In Bulletin 480, 1911, pp. 236–270. 40 cents.

Placer mining in the Fortymile and Seventymile river districts, by E. A. Porter. In Bulletin 520, 1912, pp. 211–218. 50 cents.
Placer mining in the Fairbanks and Circle districts, by C. E. Ellsworth. In Bulletin 520, 1912, pp. 240–245. 50 cents.
Gold placers between Woodchopper and Fourth of July creeks, upper Yukon River, by L. M. Prindle and J. B. Mertie, jr. In Bulletin 520, 1912, pp. 201–210. 50 cents.
The Bonnifield region, Alaska, by S. R. Capps. Bulletin 501, 1912, 162 pp. 20 cents.
A geologic reconnaissance of a part of the Rampart quadrangle, Alaska, by H. M. Eakin. Bulletin 535, 1913, 38 pp. 20 cents.
A geologic reconnaissance of the Fairbanks quadrangle, Alaska, by L. M. Prindle, with a detailed description of the Fairbanks district, by L. M. Prindle and F. J. Katz, and an account of lode mining near Fairbanks, by P. S. Smith. Bulletin 525, 1913, 220 pp. 55 cents.
The Koyukuk-Chandalar region, Alaska, by A. G. Maddren. Bulletin 532, 1913, 119 pp. 25 cents.
A geologic reconnaissance of the Circle quadrangle, Alaska, by L. M. Prindle. Bulletin 538, 1913, 82 pp. 20 cents.
Placer mining in the Yukon-Tanana region, by C. E. Ellsworth and R. W. Davenport. In Bulletin 542, 1913, pp. 203–222. 25 cents.
The Iditarod-Ruby region, Alaska, by H. M. Eakin. Bulletin 578, 1914, 45 pp. 35 cents.
Placer mining in the Ruby district, by H. M. Eakin. In Bulletin 592, 1914, pp. 363–369. 60 cents.
Placer mining in the Yukon-Tanana region, by Theodore Chapin. In Bulletin 592, 1914, pp. 357–362. 60 cents.
Lode developments near Fairbanks, by Theodore Chapin. In Bulletin 592, 1914, pp. 321–355. 60 cents.
Mineral resources of the Yukon-Koyukuk region, by H. M. Eakin. In Bulletin 592, 1914, pp. 371–384. 60 cents.
Surface water supply of the Yukon-Tanana region, Alaska, by C. E. Ellsworth and R. W. Davenport. Water-Supply Paper 342, 1915, 343 pp. 45 cents.
Mining in the Fairbanks district, by H. M. Eakin. In Bulletin 622, 1915, pp. 229–238. 30 cents.
Mining in the Hot Springs district, by H. M. Eakin. In Bulletin 622, 1915, pp. 239–245. 30 cents.
Quicksilver deposits of the Kuskokwim region, by P. S. Smith and A. G. Maddren. In Bulletin 622, 1915, pp. 272–291. 30 cents.
Gold placers of the lower Kuskokwim, by A. G. Maddren. In Bulletin 622, 1915, pp. 292–360. 30 cents.
An ancient volcanic eruption in the upper Yukon basin, by S. R. Capps. Professional Paper 95–D, 1915, pp. 59–64. 20 cents.
Mineral resources of the Ruby-Kuskokwim region, by J. B. Mertie, jr., and G. L. Harrington. In Bulletin 642, 1916, pp. 228–266. 35 cents.
The Chisana-White River district, Alaska, by S. R. Capps. Bulletin 630, 1916, 130 pp. 20 cents.
The Yukon-Koyukuk region, Alaska, by H. M. Eakin. Bulletin 631, 1916, 88 pp. 20 cents.
The gold placers of the Tolovana district, by J. B. Mertie, jr. In Bulletin 662, 1917, pp. 221–277. 75 cents.
Gold placers near the Nenana coal field, by A. G. Maddren. In Bulletin 662, 1917, pp. 363–402. 75 cents.

Lode mining in the Fairbanks district, by J. B. Mertie, jr. In Bulletin 662, 1917, pp. 403–424. 75 cents.

Lode deposits near the Nenana coal field, by R. M. Overbeck. In Bulletin 662, 1917, pp. 351–362. 75 cents.

The Lake Clark-central Kuskokwim region, Alaska, by P. S. Smith. Bulletin 655, 1918, 162 pp. 30 cents.

The Cosna-Nowitna region, Alaska, by H. M. Eakin. Bulletin 667, 1918, 54 pp. 25 cents.

The Anvik-Andreafski region, Alaska, by G. L. Harrington. Bulletin 683, 1918, 70 pp. 30 cents.

The Kantishna district, by S. R. Capps. Bulletin 687, 1919, 116 pp. 25 cents.

The Nenana coal field, Alaska, by G. C. Martin. Bulletin 664, 1919, 54 pp. $1.10.

*Mining in the Fairbanks district, by Theodore Chapin. In Bulletin 692, 1919, pp. 321–327.

*A molybdenite lode on Healy River, by Theodore Chapin. In Bulletin 692, 1919, p. 329.

*Mining in the Hot Springs district, by Theodore Chapin. In Bulletin 692, 1919, pp. 331–335.

*Tin deposits of the Ruby district, by Theodore Chapin. In Bulletin 692, 1919, p. 337.

*The gold and platinum placers of the Tolstoi district, by G. L. Harrington. In Bulletin 692, 1919, pp. 338–351.

*Placer mining in the Tolovana district, by R. M. Overbeck. In Bulletin 712, 1919, pp. 177–184.

*Mineral resources of the Goodnews Bay region, by G. L. Harrington. In Bulletin 714, 1921, pp. 207–228.

Gold lodes in the upper Kuskokwim region, by G. C. Martin. In Bulletin 722, 1922, pp. 149–161. 25 cents.

Supposed oil seepage in Nenana coal field, by G. C. Martin. In Bulletin 739, 1922, pp. 137–147. 25 cents.

The occurrence of metalliferous deposits in the Yukon and Kuskokwim regions, Alaska, by J. B. Mertie, jr. Bulletin 739–D, 1922, 17 pp. 5 cents.

The Ruby-Kuskokwim region, by J. B. Mertie, jr., and G. L. Harrington. Bulletin 754, 1924, 129 pp. Free on application.

Geology and gold placers of the Chandalar district, by J. B. Mertie, jr. In Bulletin 773, 1925, pp. ———. Free on application.

In preparation.

Geology of Fairbanks and Rampart quadrangles, by J. B. Mertie, jr.

TOPOGRAPHIC MAPS.

Circle quadrangle (No. 641); scale, 1:250,000; by T. G. Gerdine, D. C. Witherspoon, and others. 50 cents retail or 30 cents wholesale. Also in Bulletin 538, 20 cents.

Fairbanks quadrangle (No. 642); scale, 1:250,000; by T. G. Gerdine, D. C. Witherspoon, R. B. Oliver, and J. W. Bagley. 50 cents retail or 30 cents wholesale. Also in Bulletin 337, 25 cents, and Bulletin 525, 55 cents.

Fortymile quadrangle (No. 640); scale, 1:250,000; by E. C. Barnard. 10 cents retail or 6 cents wholesale. Also in Bulletin 375, 30 cents.

Rampart quadrangle (No. 643); scale, 1:250,000; by D. C. Witherspoon and R. B. Oliver. 20 cents retail or 12 cents wholesale. Also in Bulletin 337, 25 cents, and part in Bulletin 535, 20 cents.

Fairbanks special (No. 642A); scale, 1:62,500; by T. G. Gerdine and R. H. Sargent, 20 cents retail or 12 cents wholesale. Also in Bulletin 525, 55 cents.

Bonnifield region; scale, 1:250,000; by J. W. Bagley, D. C. Witherspoon, and C. E. Giffin. In Bulletin 501, 20 cents. Not issued separately.

Iditarod-Ruby region; scale, 1:250,000; by C. G. Anderson, W. S. Post, and others. In Bulletin 578, 35 cents. Not issued separately.

Middle Kuskokwim and lower Yukon region; scale, 1:500,000; by C. G. Anderson, W. S. Post, and others. In Bulletin 578, 35 cents. Not issued separately.

Chisana-White River region; scale, 1:250,000; by C. E. Giffin and D. C. Witherspoon. In Bulletin 630, 20 cents. Not issued separately.

Yukon-Koyukuk region; scale, 1:500,000; by H. M. Eakin. In Bulletin 631, 20 cents. Not issued separately.

Cosna-Nowitna region; scale, 1:250,000; by H. M. Eakin, C. E. Giffin, and R. B. Oliver. In Bulletin 667, 25 cents. Not issued separately.

Lake Clark-central Kuskokwim region; scale, 1:250,000; by R. H. Sargent, D. C. Witherspoon, and C. E. Giffin. In Bulletin 655, 30 cents. Not issued separately.

Anvik-Andreafski region; scale, 1:250,000; by R. H. Sargent. In Bulletin 683, 30 cents. Not issued separately.

Marshall district; scale, 1:125,000; by R. H. Sargent. In Bulletin 683, 30 cents. Not issued separately.

Upper Tanana Valley region; scale, 1:125,000; by D. C. Witherspoon and J. W. Bagley (preliminary edition). Free on application.

Lower Kuskokwim region; scale, 1:500,000; by A. G. Maddren and R. H. Sargent (preliminary edition). Free on application.

Ruby district; scale, 1:250,000; by C. E. Giffin and R. H. Sargent. In Bulletin 754, free on application. Not issued separately.

Innoko-Iditarod region; scale, 1:250,000; by R. H. Sargent and C. G. Anderson. In Bulletin 754, free on application. Not issued separately.

SEWARD PENINSULA.

REPORTS.

The Fairhaven gold placers of Seward Peninsula, Alaska, by F. H. Moffit. Bulletin 247, 1905, 85 pp. 40 cents.

Gold mining on Seward Peninsula, by F. H. Moffit. In Bulletin 284, 1906, pp. 132–141. 25 cents.

The gold placers of parts of Seward Peninsula, Alaska, including the Nome, Council, Kougarok, Port Clarence, and Goodhope precincts, by A. J. Collier, F. L. Hess, P. S. Smith, and A. H. Brooks. Bulletin 328, 1908, 343 pp. 70 cents.

Investigation of the mineral deposits of Seward Peninsula, by P. S. Smith. In Bulletin 345, 1908, pp. 206–250. 45 cents.

Geology of the Seward Peninsula tin deposits, by Adolph Knopf. Bulletin 358, 1908, 72 pp. 15 cents.

Recent developments in southern Seward Peninsula, by P. S. Smith. In Bulletin 379, 1909, pp. 267–301. 50 cents.

The Iron Creek region, by P. S. Smith. In Bulletin 379, 1909, pp. 302–354. 50 cents.

Mining in the Fairhaven district, by F. F. Henshaw. In Bulletin 379, 1909, pp. 355–369. 50 cents.

Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska, by P. S. Smith. Bulletin 433, 1910, 227 pp. 40 cents.

Mining in Seward Peninsula, by F. F. Henshaw. In Bulletin 442, 1910, pp. 353–371. 40 cents.

A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska, by P. S. Smith and H. M. Eakin. Bulletin 449, 1911, 146 pp. 30 cents.

Notes on mining in Seward Peninsula, by P. S. Smith. In Bulletin 520, 1912, pp. 339–344. 50 cents.

Geology of the Nome and Grand Central quadrangles, Alaska, by F. H. Moffit. Bulletin 533, 1913, 140 pp. 60 cents.

Surface water supply of Seward Peninsula, Alaska, by F. F. Henshaw and G. L. Parker, with a sketch of the geography and geology by P. S. Smith and a description of methods of placer mining by A. H. Brooks; including topographic reconnaissance map. Water-Supply Paper 314, 1913, 317 pp. 45 cents.

Placer mining on Seward Peninsula, by Theodore Chapin. In Bulletin 592, 1914, pp. 385–396. 60 cents.

Lode developments on Seward Peninsula, by Theodore Chapin. In Bulletin 592, 1914, pp. 397–407. 60 cents.

Iron-ore deposits near Nome, by H. M. Eakin. In Bulletin 622, 1915, pp. 361–365. 30 cents.

Placer mining in Seward Peninsula, by H. M. Eakin. In Bulletin 622, 1915, pp. 366–373. 30 cents.

Lode mining and prospecting on Seward Peninsula, by J. B. Mertie, jr. In Bulletin 662, 1917, pp. 425–449. 75 cents.

Placer mining on Seward Peninsula, by J. B. Mertie, jr. In Bulletin 662, 1917, pp. 451–458. 75 cents.

*Tin mining in Seward Peninsula, by G. L. Harrington. In Bulletin 692, 1919, pp. 353–361.

*Graphite mining in Seward Peninsula, by G. L. Harrington. In Bulletin 692, 1919, pp. 363–367.

*The gold and platinum placers of the Kiwalik-Koyuk region, by G. L. Harrington. In Bulletin 692, 1919, pp. 368–400.

*Mining in northwestern Alaska, by S. H. Cathcart. In Bulletin 712, 1919, pp. 185–198.

*Mining on Seward Peninsula, by G. L. Harrington. In Bulletin 714, 1921, pp. 229–237.

Metalliferous lodes of southern Seward Peninsula, by S. H. Cathcart. In Bulletin 722, 1922, pp. 163–261. 25 cents.

The geology of the York tin deposits, Alaska, by Edward Steidtmann and S. H. Cathcart. Bulletin 733, 1922, 125 pp. 30 cents.

TOPOGRAPHIC MAPS.

Seward Peninsula; scale, 1:500,000; compiled from work of D. C. Witherspoon, T. G. Gerdine, and others, of the Geological Survey, and all available sources. In Water-Supply Paper 314, 45 cents. Not issued separately.

Seward Peninsula, northeastern portion, reconnaissance map (No. 655); scale, 1:250,000; by D. C. Witherspoon and C. E. Hill. 50 cents retail or 30 cents wholesale. Also in Bulletin 247, 40 cents.

Seward Peninsula, northwestern portion, reconnaissance map (No. 657); scale, 1:250,000; by T. G. Gerdine and D. C. Witherspoon. 50 cents retail or 30 cents wholesale. Also in Bulletin 328, 70 cents.

Seward Peninsula, southern portion, reconnaissance map (No. 656); scale, 1:250,000; by E. C. Barnard, T. G. Gerdine, and others. 50 cents retail or 30 cents wholesale. Also in Bulletin 328, 70 cents.

Seward Peninsula, southeastern portion, reconnaissance map (Nos. 655–656); scale, 1:250,000; by E. C. Barnard, D. L. Reaburn, H. M. Eakin, and others. In Bulletin 449, 30 cents. Not issued separately.

Nulato-Norton Bay region; scale, 1:500,000; by P. S. Smith, H. M. Eakin, and others. In Bulletin 449, 30 cents. Not issued separately.

Grand Central quadrangle (No. 646A); scale, 1:62,500; by T. G. Gerdine, R. B. Oliver, and W. R. Hill. 10 cents retail or 6 cents wholesale. Also in Bulletin 533, 60 cents.

Nome quadrangle (No. 646B); scale, 1:62,500; by T. G. Gerdine, R. B. Oliver, and W. R. Hill. 10 cents retail or 6 cents wholesale. Also in Bulletin 533, 60 cents.

Casadepaga quadrangle (No. 646C); scale, 1:62,500; by T. G. Gerdine, W. B. Corse, and B. A. Yoder. 10 cents retail or 6 cents wholesale. Also in Bulletin 433, 40 cents.

Solomon quadrangle (No. 646D); scale, 1:62,500; by T. G. Gerdine, W. B. Corse, and B. A. Yoder. 10 cents retail or 6 cents wholesale. Also in Bulletin 433, 40 cents.

NORTHERN ALASKA.

REPORTS.

A reconnaissance in northern Alaska across the Rocky Mountains, along Koyukuk, John, Anaktuvuk, and Colville rivers and the Arctic coast to Cape Lisburne in 1901, by F. C. Schrader, with notes by W. J. Peters. Professional Paper 20, 1904, 139 pp. 40 cents.

Geology and coal resources of the Cape Lisburne region, Alaska, by A. J. Collier. Bulletin 278, 1906, 54 pp. 15 cents.

Geologic investigations along the Canada-Alaska boundary, by A. G. Maddren. In Bulletin 520, 1912, pp. 297–314. 50 cents.

The Noatak-Kobuk region, Alaska, by P. S. Smith. Bulletin 536, 1913, 16 pp. 40 cents.

The Koyukuk-Chandalar region, Alaska, by A. G. Maddren. Bulletin 532, 1913, 119 pp. 25 cents.

The Canning River region of northern Alaska, by E. de K. Leffingwell. Professional Paper 109, 1919, 251 pp. 75 cents.

A reconnaissance of the Point Barrow region, Alaska, by Sidney Paige and others. Bulletin 772. Free on application.

TOPOGRAPHIC MAPS.

Koyukuk River to mouth of Colville River, including John River; scale, 1:1,250,000; by W. J. Peters. In Professional Paper 20, 40 cents. Not issued separately.

Koyukuk and Chandalar region, reconnaissance map; scale, 1:500,000; by T. G. Gerdine, D. L. Reaburn, D. C. Witherspoon, and A. G. Maddren. In Bulletin 532, 25 cents. Not issued separately.

Noatak-Kobuk region; scale, 1:500,000; by C. E. Giffin, D. L. Reaburn, H. M. Eakin, and others. In Bulletin 536, 40 cents. Not issued separately.

Canning River region; scale, 1:250,000; by E. de K. Leffingwell. In Professional Paper 109, 75 cents. Not issued separately.

North Arctic coast; scale, 1:1,000,000; by E. de K. Leffingwell. In Professional Paper 109, 75 cents. Not issued separately.

Martin Point to Thetis Island; scale, 1:125,000; by E. de K. Leffingwell. In Professional Paper 109, 75 cents. Not issued separately.

Northwestern part of Naval Petroleum Reserve No. 4, Alaska; scale, 1:500,000; by E. C. Guerin, Gerald Fitz Gerald, and J. E. Whitaker (preliminary edition). Free on application. Surveyed for Department of the Navy.

ADDITIONAL COPIES

OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
40 CENTS PER COPY

△